IRRIGATION Agriculture IN THE WEST

U. S. DEPARTMENT OF AGRICULTURE MISCELLANEOUS PUBLICATION NO. 670

OFFICE OF THE SECRETARY

FOREWORD

This publication has been prepared in the interest of a permanent irrigation agriculture. Irrigation has played an important role in the remarkable achievement by farmers of this Nation in meeting wartime and postwar production goals. It may play an even greater part in our future agricultural production. Today, as never before, we are coming to realize that the food needs of our growing population and the establishment of desirable trade relations with other nations will require the maintenance of efficient, high-level agricultural production.

Efficient and sustained agricultural production at high levels may in turn require temporary or full retirement from intensive cultivation of many million acres of damaged land. Among the ways to make up for losses that have been caused largely by improper tillage and erosion in years past, is further use of our arid land by irrigation and more adequate use of our humid lands by drainage. In this publication we are concerned with the important role that irrigation plays in our Nation's agriculture and its possibilities and problems.

The great potential of the United States for agricultural production on irrigated lands must be developed wisely. Scarce water must be husbanded for efficient use. Sound principles must be followed if expanded irrigation development is to result in profitable farm incomes and contribute to national prosperity. River-basin planning must encompass all the interrelated uses of land and water. A balance must be found between the competing uses of water for irrigation, domestic consumption, power development, fish and wildlife, recreation, and navigation. The beneficial uses of water must be developed so that the destructive effects of floods, erosion of topsoil, and siltation of stream beds and reservoirs can be reduced to a minimum. Equitable means must be found for allocating cost of development among the several beneficial uses.

If irrigation is to contribute the fullest possible benefits, water supplies now flowing unused to the sea must be developed. Also the wastage of water through canal seepage and improper irrigation practices must be reduced. And further, the soil and water-flow stability of the watersheds must be improved and safeguarded through protection and management in order to arrest still other forces now causing deterioration of irrigated lands and works. This manifold job calls for new dams, tunnels, canals, and other large-scale works, as well as lesser works. These structures, supplemented by other measures, are necessary to help us manage our water supplies efficiently and reduce floods, and at the same time make more water available for use. It calls for more efficient conveyance of water to the land and for use of this water on productive lands by the best known methods of application. It calls for use and treatment of all the land in watersheds—whether forest, range, or cropland—according to capability and need. It requires that local, State, and Federal agencies work together in the closest possible harmony.

The United States Department of Agriculture recognizes its responsibility and accepts the challenge to aid the development and expansion of agriculture through irrigation in the West. Water and land are the great natural resources which together are the foundation for agriculture. In the West this Department is helping to combine these factors to achieve an abundant, prosperous, and permanent agriculture.

Charles F. Brannan,
Secretary of Agriculture

Issued November 1948

ACKNOWLEDGMENT

Elco L. Greenshields, Bureau of Agricultural Economics, had the primary responsibility in the preparation of this report, in consultation with Raymond L. Stevens of the Office of the Secretary. Among others who contributed in various ways are Wells A. Hutchins and C. E. Busby of the Soil Conservation Service and Carleton P. Barnes of the Bureau of Plant Industry, Soils and Agricultural Engineering, of the Agricultural Research Administration. Chester C. Hampson, now with the Bureau of Reclamation, started some work looking toward this end when he was in the Bureau of Agricultural Economics. Robert F. Turnure, Bureau of Agricultural Economics, supervised the drafting work by the cartographic units of that Bureau and the Soil Conservation Service. The latter agency drafted the map "Major Land Use Areas" and performed the necessary photographic work for all colored maps.

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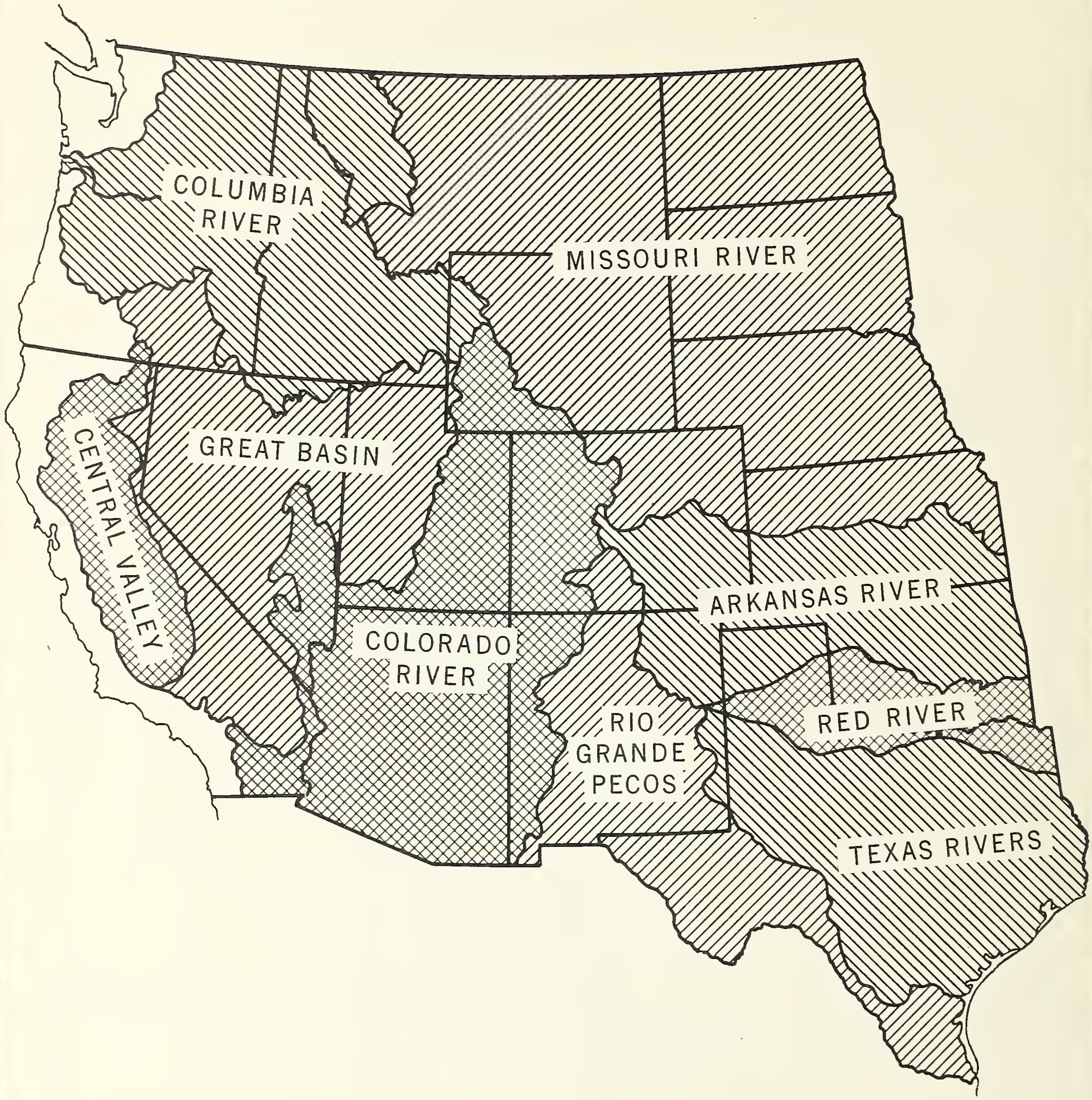
MAJOR RIVER BASINS OF THE WEST



Irrigation in Agricultural Production

Prepared in the Bureau of Agricultural Economics

IN this publication we view the West as a distinct agricultural region because of the widespread dry climates and because of the great part that irrigation plays in crop production. Without irrigation, the West would still be an important agricultural region as a dry-land wheat-producing area and as a vast grazing area capable of producing a notable share of the country's demand for beef, mutton, hides, and wool. With irrigation, the West has become a region of utmost importance to the Nation, for here are grown many agricultural products—fruits, vegetables, sugar beets, and nearly all types of crops.

The 17 Western States comprise three-fifths of the area of the continental United States. These States have 22 percent of the total U. S. population; 23 percent of the farm population. From these States we get a little more than one-third of our total farm output (fig. 1). As measured by the farm values of crops in 1947, we get three-tenths of our livestock and livestock products, nearly four-fifths of our wool production, two-thirds of our mutton and lamb, one-half of our beef, and one-fourth of our dairy and poultry production.

Two-fifths of the Nation's crop production is in the West. Nearly four-fifths of the aggregate of the food grains—wheat, rice, rye, and buckwheat—are produced in the Western States. The bread-basket area of the country is centered in the Great Plains. From the six Plains States, the tier including the Dakotas in the north and Texas in the south, comes nearly three-fifths of the Nation's food grains. Washington, Montana, and Colorado are other big producers of food grains in the West.

Of the feed grains—corn, oats, barley, and sorghum—about one-fourth is grown in the 17 Western States, most of it being in the 6 Plains States. Less than 5 percent of the total feed-grain production of the United States comes from the 11 far Western States. Virtually all of the sorghum grains are grown in the West and nearly four-fifths of the barley. A small part of the Corn Belt proper extends into South Dakota and Nebraska, and this adds production to the total for the West that does not strictly belong to the western region.

Of the hay and forage production, close to two-fifths is in the West. One-third of the seed crops come from western

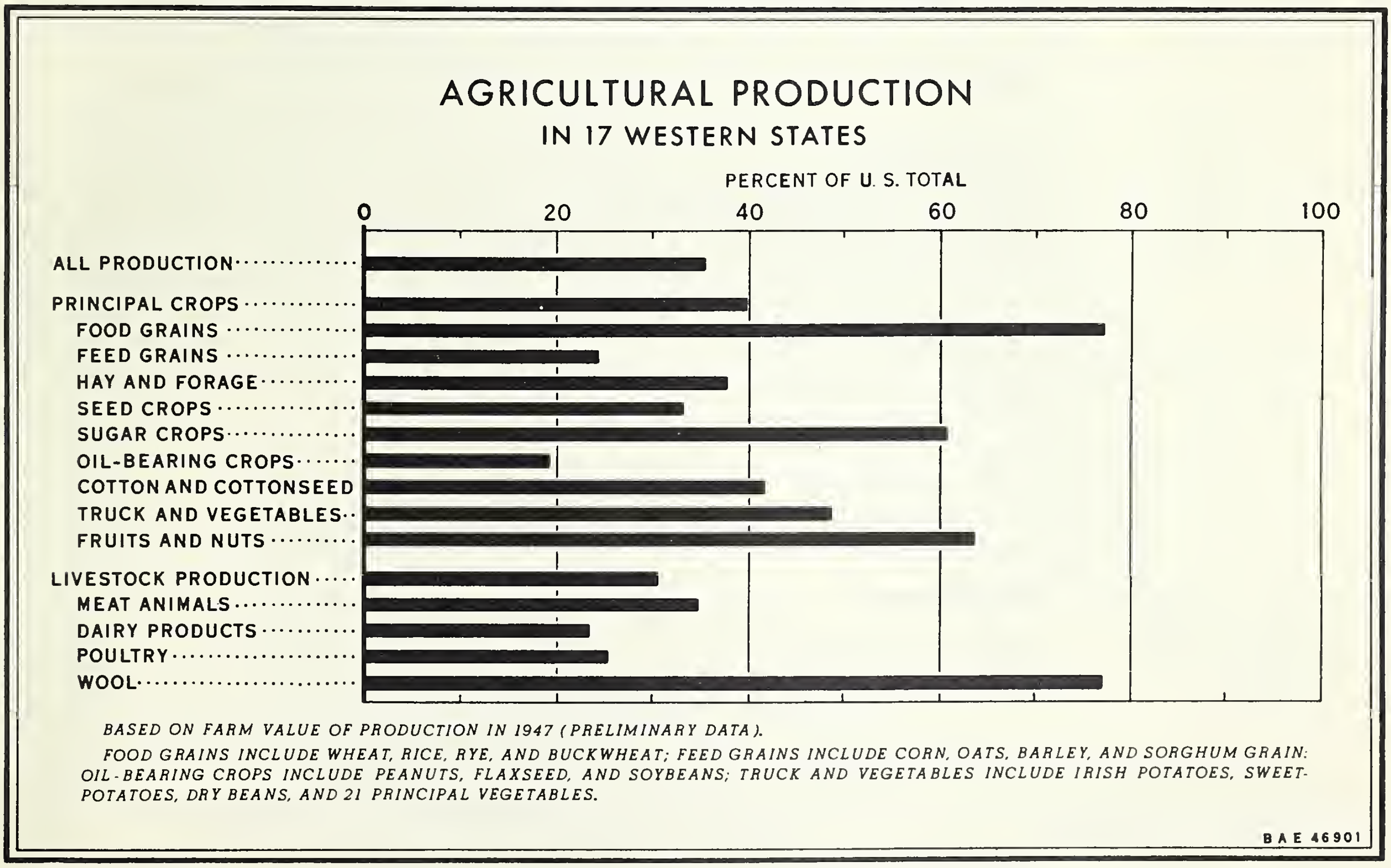
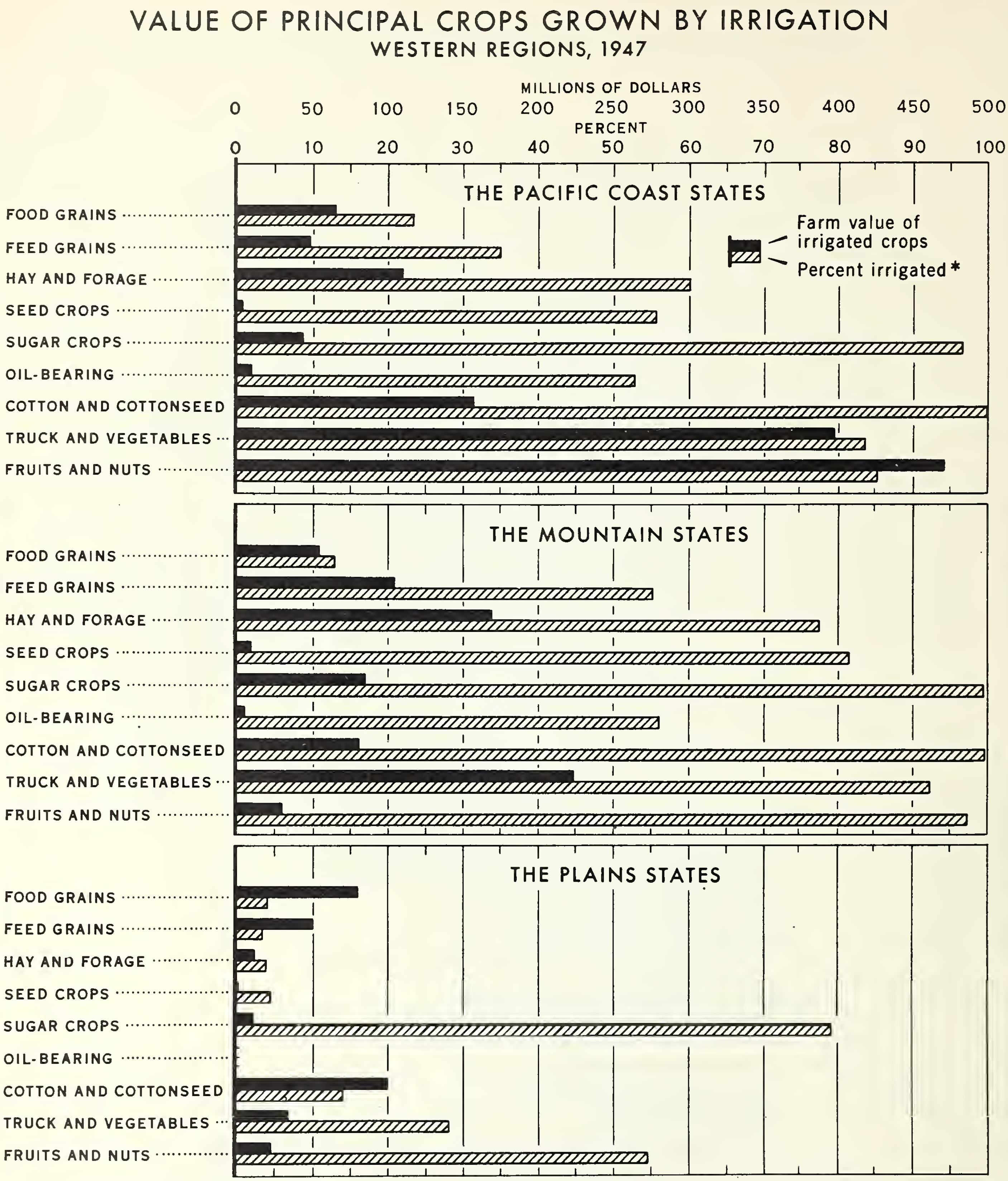


FIGURE 1.



PACIFIC STATES INCLUDE WASHINGTON, OREGON, AND CALIFORNIA; MOUNTAIN STATES INCLUDE MONTANA, IDAHO, WYOMING, COLORADO, NEW MEXICO, ARIZONA, UTAH, AND NEVADA; PLAINS STATES INCLUDE NORTH DAKOTA, SOUTH DAKOTA, NEBRASKA, KANSAS, OKLAHOMA, AND TEXAS.

**PERCENTAGE OF THE FARM VALUE OF THE TOTAL PRODUCTION OF EACH CROP GROUP WITHIN EACH REGION THAT IS PRODUCED ON IRRIGATED LAND.*

BAE 46902

ESTIMATED MAINLY ON THE BASIS OF A PROJECTION OF DATA FROM THE 1940 CENSUS OF AGRICULTURE

FIGURE 2.

farms and ranches. Three-fifths of the sugar crops of the Nation are produced in the West—the greater part of our supply that comes from sugar beets. All of the sugarcane is grown in the humid South. By irrigating, the West makes a big contribution to the total supply of vegetables and fruits; nearly one-half of all the truck and vegetable crops are raised in the West and over three-fifths of the fruits.

In western crop production irrigation plays a very significant part (fig. 2). Of all the crop production in the 17 Western States, about 30 percent is from irrigated land. (Excluded from this production are forestry and nursery products and the value of irrigated pasture.) In terms of the 1947 farm value of these crops this irrigated production amounts to 2.4 billion dollars. In the three Pacific Coast States, 70 percent of all crop production is grown under irrigation. In these States alone the farm value of irrigated crops was 1.3 billion dollars in 1947. In California about 85 percent of all crops are irrigated, in Oregon around 35 percent, and in Washington some 45 percent.

Of the total production in the Mountain States about 60 percent of the total crop production is from irrigated land—this production had a farm value of more than ¾ billion dollars in 1947. In Nevada and Arizona virtually all crops are irrigated; in Utah and Wyoming irrigated crop production is between 75 and 85 percent of the total. Montana has the lowest relative irrigated production of the Mountain States, in view of its large production of dry-land wheat.

In the six Plains States only about 6 percent of the total crop production comes from irrigated land. In the Plains, Texas leads in irrigated production which accounts for 15 percent of all of its crop production. Irrigation is used for about 10 percent of the production in Nebraska.

There are wide differences in the extent to which irrigation is practiced in growing the various crops in the 17 Western States. For instance, only about 3 percent of the wheat production is irrigated, whereas virtually 100 percent of the rice, sugar beets, and citrus fruits, are grown with irrigation. Two-fifths of all hay and forage production in the 17 Western States is irrigated. Around one-tenth of the feed grains are irrigated, about two-fifths of the seed crops, about one-tenth of the oil-bearing crops, over one-third of the cotton, nearly four-fifths of the vegetables, and over four-fifths of the fruit.

In the Pacific Coast States about a fourth of the food grains are grown under irrigation, and in the Mountain States about 15 percent. In the Plains the irrigation of food grains, except rice, is insignificant. The value of cotton produced under irrigation exceeds the value of any other crop grown under irrigation in the Plains, though a larger part of the total production of several other crops are produced under irrigation in the Plains than is the case with cotton.

Irrigation is not undertaken at all in a large part of the Plains States (fig. 3). In these States two-fifths of the counties had no irrigation when the 1940 census was taken. In another two-fifths of the counties there was only a little irrigation.

Irrigation has expanded into some additional counties since then; in other counties the irrigation practiced by a few farmers has been discontinued because of the increased rainfall in recent years. The irrigation of small acreages of fruits, vegetables, and similar crops fluctuates greatly from year to year in the subhumid parts of the West. Extension of the areas of irrigated field crops has not been large within the last several years, but there has been expansion in a few places where ground water is being developed and on several new surface water projects.

In the Mountain and Pacific States there are only six counties in which no irrigation is carried on. In these counties there is little agricultural production. In 68 counties in the 11 far Western States not much irrigation is practiced. These counties are chiefly in the humid part of the Washington and Oregon coast, in the wheat belt of Washington, Montana, and eastern Colorado. They also include some counties almost wholly given over to grazing.

In a large part of the far Western States 80 percent or more of total crop production comes from irrigated land. In a third of the agricultural counties in the Pacific States irrigated crops represent four-fifths or more of crop production. In the eight Mountain States irrigated crops account for most of the crop production in at least half of the counties. In the Plains States irrigation is important in crop production along the Rio Grande River in Texas, the North Platte in Nebraska, the Arkansas in western Kansas, and along the Belle Fourche and Cheyenne in South Dakota. Irrigation also plays a relatively large part in crop production in the High Plains ground-water area, and in the rice areas of Texas.

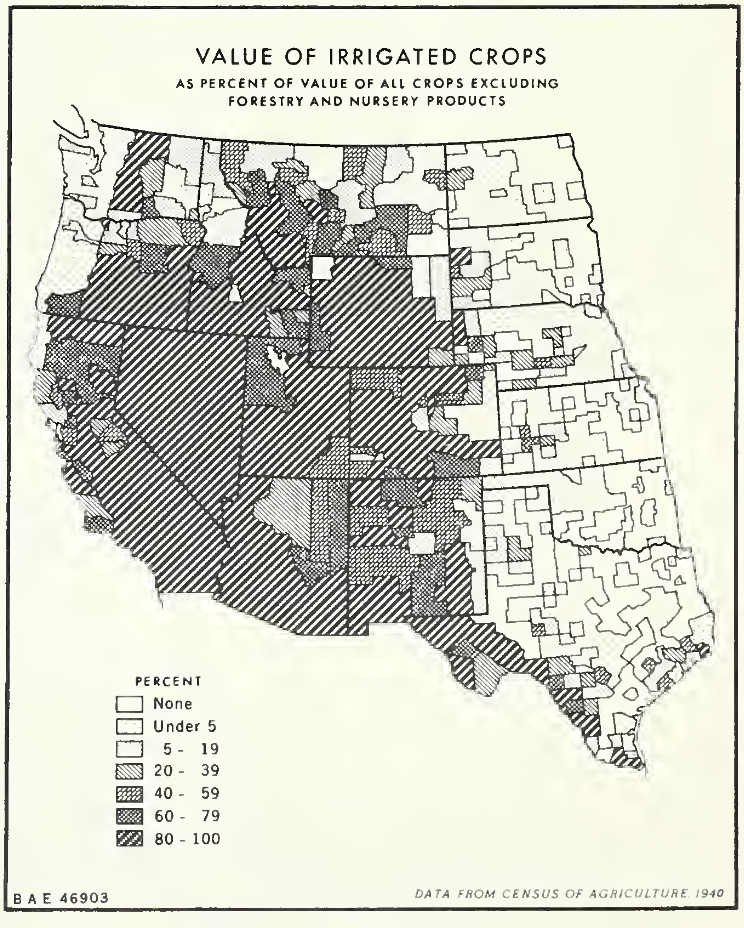


FIGURE 3.

Organization for Irrigation Purposes[1]

IRRIGATION of agricultural land usually requires the construction, operation, and maintenance of facilities to divert and convey water from its source to the land to be irrigated. Because of the need for having water from a single source available to several farms and the need for equitable distribution of the water among the several users of the common supply, cooperation of water users in financing and utilizing the means for irrigating has been important from the earliest days. Cooperation has prevailed throughout the histories of many irrigation enterprises.

A substantial part of irrigation in the West has always involved the employment of organizations of one kind or another to supply and distribute water. The organization is the legal form of an enterprise which owns or operates the irrigation works that supply water to a group of users. The type of organization determines the existing powers of the enterprise and its relations with the water users. There are noteworthy differences between types of irrigation organizations (1) in the character of the security they can offer for loans for construction purposes and (2) in their powers to collect revenue from the water users to repay the loans and to operate and maintain the irrigation systems. Throughout the years continued shifts have taken place in the nature and relative importance of organizations that serve the irrigators, but except for commercial enterprises which are set up to sell water to the users at a profit, some form of either private or public cooperation has been incorporated in their structure.

As irrigation agriculture expanded the stream waters available for further development became scarcer and less accessible, so that more extensive and costlier irrigation systems and, in many cases, storage reservoirs were needed. Projects increased in size, from the individual and small cooperative establishments diverting water from a single stream to those with facilities for serving large areas or even entire irrigated valleys and, more recently, to large-scale multiple-purpose projects. Adequate powers of financing these developments and of obtaining revenue from the water users were necessary. To meet these needs, types of organizations developed from small informal cooperatives to incorporated companies, some cooperative and others commercial, and to public districts having the taxing power.

Individual and Partnership Enterprises

Individual and partnership enterprises belong to individual farmers or to neighboring farmers who control them without formal organization. Organizationally, they furnish the simplest means for providing irrigation water and facilities. The works controlled by them are largely for the gravity diversion of water from streams or springs, or for pumping from wells. Partnership enterprise organizations may be quite informal. However, the responsibilities and privileges of each party to a partnership are recognized and enforceable under State laws. Partnership enterprises and individually operated irrigation works account for about one-third of the irrigated area in the West (fig. 4). The relative importance of partnership and individual enterprises declined from the turn of the century until about 1930. Since then the expansion of pumped-well irrigation has reversed the apparent long-time downward trend. Individual enterprises will continue to be the predominant type in many areas that depend largely upon ground water as their irrigation supply. But the trend toward large-scale development of the entire watersheds of major streams may result in accelerating the absorption of such enterprises by large projects.

Cooperative or Mutual Enterprises

Cooperative or mutual enterprises are controlled by the water users by means of private organizations, incorporated or unincorporated. The most common form of organization of these enterprises is the stock company, formed under the general corporation law of the State, and known in many places as the mutual irrigation company or mutual water company. Shares of stock are owned by the water users; they represent proportionate amounts of available water as well as proportionate ownership of the enterprise facilities. Unincorporated associations, which are controlled through written or oral agreements between the members, may be considered as the next stage of private cooperative organization beyond the simple partnership.

Incorporated companies, which serve irrigated areas ranging from less than 100 to more than 200,000 acres each, may be considered as the advanced stage. Many cooperative enterprises built their own irrigation systems, and many others acquired systems that had been built by commercial com-

[1] Farmers today, more than at any previous time, appreciate the value of local group organizations in helping to solve their irrigation and water conservation problems. The district or local governmental type of organization, which for many decades has been used to supply much of the water to western farm lands, has more recently been applied to the solution of combined land and water problems through the medium of soil conservation districts.

The primary function of the soil conservation district is to bring about maximum cooperative effort among farmers and ranchers, and their irrigation, drainage, and other kinds of organizations concerned with land and water. They are the medium through which basic adjustments in land and water uses may be achieved. They facilitate the improvement and protection of the smaller types of storage, conveyance, and disposal works. They are further the means through which the land resources of the watershed can be conserved. At present, more than 950 of these districts have been organized in the 17 Western States. They include about 11 million acres of irrigated lands and about 600 million acres of all types of lands.

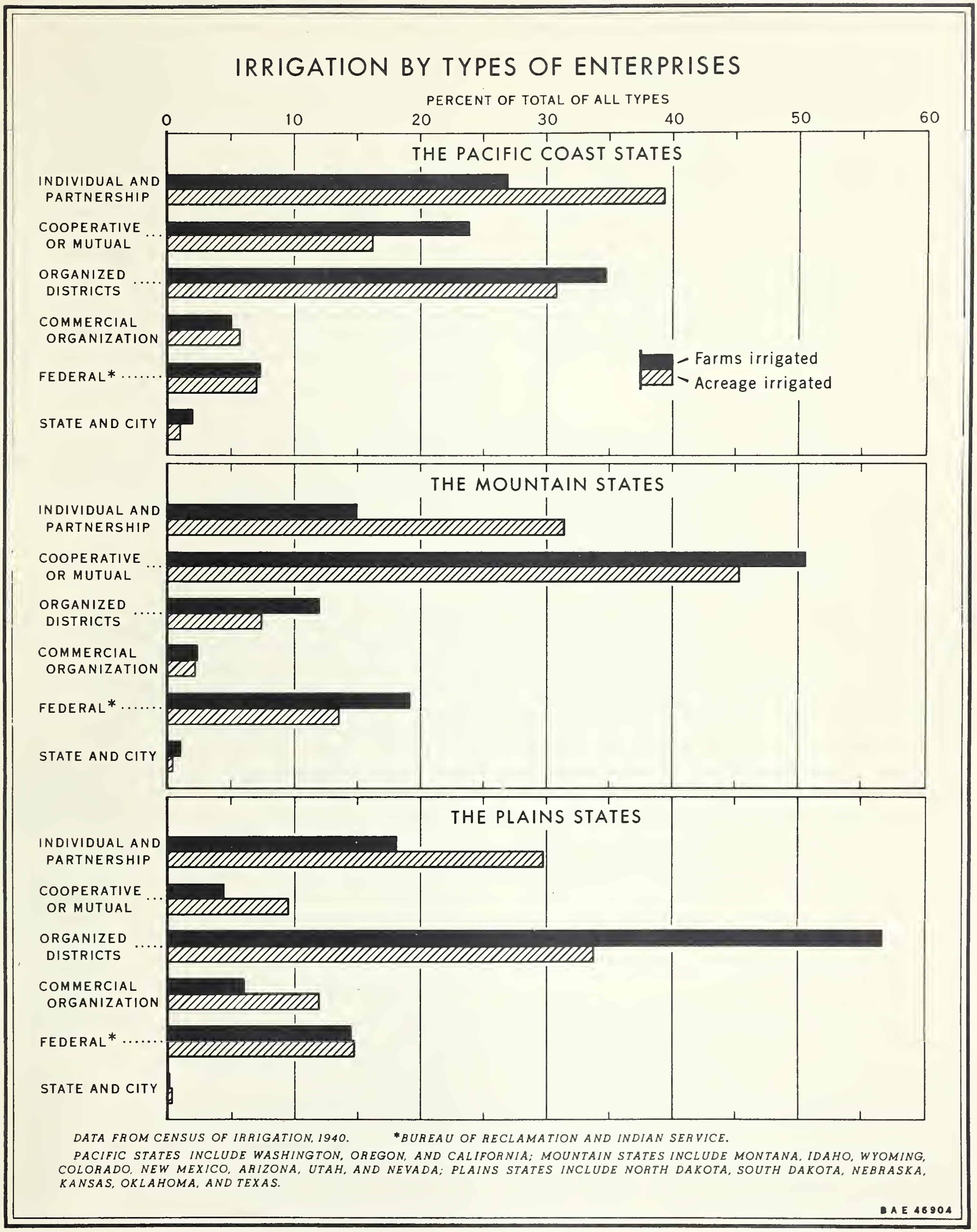


FIGURE 4.

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panies. Transfers of some commercially built systems to mutual-company organizations had been planned as a part of combined land-and-water developments or of water developments alone, and others resulted from failure of the development agency or from unsuccessful operation of irrigation works on a commercial basis.

Included in the classification of cooperative enterprises are the "community ditches" or "public acequias" organized and operated in accordance with old Spanish-American customs, and "lateral" companies which distribute water beyond the places where the responsibility of the parent organization ends.

About one-third of the irrigated area of the West is served by private cooperative enterprises. In the eight Mountain States such enterprises supply water for one-half of the farms irrigated. In the Pacific Coast States nearly one-fourth of the irrigated farms rely on cooperative forms of organization of irrigation enterprises.

District Enterprises

The virtual necessity in certain areas for requiring all lands within proposed irrigation projects to share in the cost in order to make irrigation possible, and for offering the security of tax liens for large indebtedness, resulted in the enactment of State laws providing for the establishment of public or quasi-public corporations known as irrigation districts. Beginning with the adoption of the Wright Act by California in 1887, all of the 17 Western States, during the ensuing years, have enacted irrigation-district laws. These laws in the different States vary with regard to the details of district formation and operations but they all embody the same fundamental principles. The organization of a district under these laws, and the construction or acquisition of its irrigation works and their operation and maintenance, are not dependent upon the consent and agreemen of all landowners within the boundaries of the district area to be served by the works; but a substantial proportion must consent. Through taxing authority, districts can levy assessments against all lands within their boundaries that benefit from the works of the district, thus making it possible to spread the cost of the district operations over the entire benefited area, whether or not a minority of the landowners favor the irrigation development. Thus the district is a public cooperative undertaking in which the majority cooperate voluntarily and an unwilling minority may be forced to cooperate. In the private mutual company the cooperation is wholly voluntary.

Irrigation districts organized under State laws have grown steadily in importance and have issued bonds in large aggregate amounts. Public districts have also been formed under State laws, other than the irrigation-district laws, for irrigation and other primary purposes, such as power development and flood control. Some such districts have the taxing power; others depend for revenue wholly upon the sale of water or of water and power. At present, district enterprises have constructed or bought and now maintain and operate irrigation works that serve about one-fifth of all of the irrigated land in the West.

Commercial Enterprises

Commercial enterprises supply water, for a price, to farmers who own no interest in the works. Therefore they are not cooperative water users' organizations. Their importance has declined as that of irrigation districts has increased. Most of the construction or development companies, which were not intended to be permanent operating organizations, have been succeeded by mutual companies or districts; and the owners of many enterprises who had hoped to profit from the sale of water each season found their operations unprofitable and sold the irrigation systems to water-user organizations. Commercial enterprises now serve only about 5 percent of the existing irrigated area. The degree of their importance varies in different parts of the West. In California, a large number of commercial companies still operate works that supply water to about 7 percent of the irrigated area of the State, many of them furnishing water for domestic and industrial purposes as well. In Texas, too, commercial irrigation companies are relatively important. In 1940 about one-fifth of the million acres irrigated in that State was supplied water by these concerns. Recent indications are, that in the Texas rice area, commercial enterprises have increased in the last few years. But, generally, development in the West by commercial irrigation companies is largely a thing of the past.

Federal Enterprises

At the time of the census of irrigation in 1940, the Federal Government, through the Bureau of Reclamation and the Office of Indian Affairs of the Department of the Interior, had built projects that furnished the primary water supply for 11 percent of the total irrigated area of the West. In addition, works constructed by the Bureau of Reclamation furnished a supplemental water supply for 7 percent of the irrigated western lands. Thus, by 1940 a total of about one-sixth of the irrigated land in the West received all or a part of its water supply from works constructed by the Federal Government. Federal activities since 1940 have added somewhat to the area served by Federal projects.

In the 8 years since the 1940 census the irrigated area for which facilities of the Bureau of Reclamation supply primary or supplemental water has increased by about 1,321,000 acres. In 1947 the total area supplied by these facilities was 4,462,000 acres. Of this area, 2,063,000 acres were irrigated from works constructed entirely by the Bureau of Reclamation.

The area irrigated in enterprises of the Bureau of Indian Affairs increased from 515,765 acres at the time of the 1940 irrigation census to 544,391 acres in 1946. This is an increase of about 6 percent. The increase in the last 8 years for all Federal enterprises is about 37 percent.

The Bureau of Reclamation deals with organizations of water users on the Federal reclamation projects rather than directly with individual users. In most cases these organizations are irrigation districts formed for the purpose of entering into contracts with the United States for the repayment of construction charges and operation and maintenance costs and for the eventual operation of the irrigation systems.

Or they are districts that own their irrigation systems and contract with the Government for supplemental water supplies. On a few projects similar contractual arrangements are found with private incorporated cooperative companies known as water users' associations. Many projects, or divisions of projects, built by that Bureau are now being operated by these districts or water users' associations. On a few of the Indian Affairs projects, irrigation districts covering the "white" lands have been formed to cooperate with the Office of Indian Affairs.

Federal activities in irrigation will continue to grow in importance. Development of many of the remaining sources of water supply will involve large-scale projects with investments beyond the resources of private capital. Furthermore, the Federal Government has interests and responsibilities with respect to irrigation and other projects that involve the navigability of streams and control of floods, as well as with respect to relations between States in the use of interstate streams. These interests and responsibilities will require Federal participation in many future water-development projects, even aside from the furnishing of capital.

State and City Enterprises

A few irrigation enterprises have been undertaken by the States, under special legislation. Some of these projects are still operating. In addition, various State institutions have independent irrigation systems serving institutional lands.

Some cities in several Western States have established sewage farms to utilize the effluent from the sewage-disposal plants for irrigating crops, and some permit such use by individuals. Other cities, notably in Utah and California, make substantial deliveries of irrigation water in conjunction with their municipal water works. In all, State and city enterprises supply water for the irrigation of about 100,000 acres of land.

The Future of Irrigation Development

SINCE the time of the first settlements in the West, great changes have been brought about in the original capacities of the region for plant growth and agricultural production. Farmers have maintained a constant struggle to overcome the uncertainties of rainfall, the shortness of growing seasons in the high altitudes, the destructive effects of the hard beating rains when they come, and other hazards arising out of an environment naturally unsuited to intensive-crop farming. By irrigating, by the adoption of special moisture-conserving tillage practices, by plant breeding for selection of drought-resisting and quicker maturing varieties of crops, and by other means, the natural obstacles to an intensive agriculture are being overcome.

The original plant growth of the West shows clearly that its climate and physical features are generally unfavorable to crop production (fig. 5). Originally the semiarid, arid, and desert valleys were covered with short grass and desert shrubs. Many of these valleys now show no resemblance to their original state. They are valleys of abundantly producing agricultural lands, made possible through irrigation.

Great as has been the achievement of the West in developing its limited water resources for irrigation, they have not reached their maximum potential. The West works toward expanded development of irrigation and toward a more effective conservation of its water supplies. For continued growth and for the maintenance of a permanent agriculture, it must look toward further development of its water resources.

The extent and rate of further western irrigation development depends mainly on three basic factors—the availability of suitable soils, the availability of water, and the extent of Federal and State activities in the field of irrigation development. Among other factors to be considered are the need for the products from additional land and the costs of developing new land.

New Era

It can be said that the development of lands of the West for irrigated agriculture has entered a new era. Before the entry of the Federal Government into the field of reclamation, with the enactment of the Reclamation Act of 1902, irrigation activities had been largely a matter of individual or private-group undertaking. Naturally those land and water resources that were most easy to develop for irrigation had received the major efforts of private enterprise. With the enactment of Federal legislation and the participation of the Federal Government in the construction of irrigation-reclamation projects, emphasis was more and more directed toward more complicated projects whose construction had been beyond the scope of private interests.

Because of the limiting features in early reclamation law that held to the concept of more-or-less single-purpose projects, and because of the necessity for repayment of all construction charges by water users and the relatively small sums of money made available for Federal projects, the Federally sponsored program initially also developed the resources that were most easily developed. But gradually irrigation projects have become more complex. In general, the development of the remaining areas suitable for irrigation will require much larger over-all and unit investments than can reasonably be made by private enterprise for repayment out of the returns from irrigation.

Any considerable expansion of our irrigated area must now be viewed as one segment of comprehensive multipurpose projects which integrate the development of land and water resources to produce both private and public benefits from agriculture, power, flood and sediment control, maintenance of fish and wildlife resources, and domestic and industrial water supply.

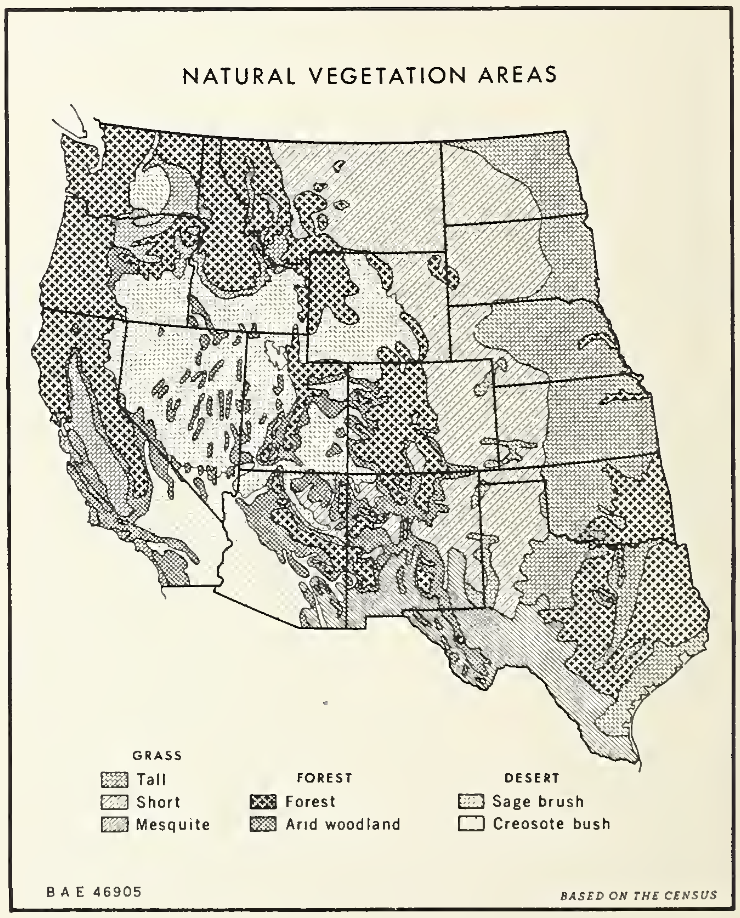


FIGURE 5.

irrigation development.

IRRIGATED AND POTENTIALLY IRRIGABLE LANDS
GENERALIZED AREA DELINEATIONS

Irrigated areas

Potentially irrigable areas

Areas containing scattered irrigated tracts utilizing groundwater

SOURCES: U. S. DEPARTMENT OF INTERIOR, BUREAU OF RECLAMATION, AND OTHER STATE AND FEDERAL MAPS AND REPORTS

SCALE

0 50 100 150 200 MILES

BASE MAP FROM "MAP OF THE LANDFORMS OF THE UNITED STATES" (REVISED 1946) PREPARED AT THE INSTITUTE OF GEOGRAPHICAL EXPLORATION, HARVARD UNIVERSITY, BY ERWIN RAISZ

FIGURE 6.

TABLE 1.—*Summary of estimates of potential irrigation development*

Region and State	Area irrigated [1]	NRB estimate of ultimate irrigable area [2]	Further development needed to reach ultimate	Further development under way and proposed by Bureau of Reclamation [3]: New lands	Further development under way and proposed by Bureau of Reclamation [3]: Supplemental water	Percentage which new irrigation proposals are of further development needed to reach NRB estimate	Extent supplemental water project proposals cover present irrigated area
Pacific:	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Percent*	*Percent*
Washington	520, 153	2, 655, 500	2, 135, 347	1, 546, 800	108, 170	72. 4	20. 8
Oregon	1, 129, 059	3, 512, 900	2, 383, 841	1, 065, 580	211, 700	44. 7	18. 8
California	4, 952, 819	16, 673, 000	11, 720, 181	1, 763, 500	2, 110, 000	15. 0	42. 6
Total	6, 602, 031	22, 841, 400	16, 239, 369	4, 375, 880	2, 429, 870	26. 9	36. 8
Mountain:							
Idaho	2, 026, 280	3, 755, 500	1, 729, 220	792, 390	978, 430	45. 8	48. 3
Nevada	674, 204	1, 065, 600	391, 396	97, 800	99, 780	25. 0	14. 8
Arizona	736, 027	1, 578, 800	842, 773	254, 535	607, 660	30. 2	82. 6
Utah	1, 124, 081	2, 164, 900	1, 040, 819	158, 647	271, 725	15. 2	24. 2
Montana	1, 555, 480	3, 865, 600	2, 310, 120	1, 037, 160	342, 900	44. 9	22. 0
Wyoming	1, 353, 873	4, 060, 600	2, 706, 727	838, 100	332, 710	31. 0	24. 6
Colorado	2, 698, 579	5, 036, 300	2, 337, 721	722, 045	1, 882, 315	30. 9	69. 7
New Mexico	534, 640	1, 090, 800	556, 160	210, 287	146, 250	37. 8	27. 4
Total	10, 703, 164	22, 618, 100	11, 914, 936	4, 110, 964	4, 661, 770	34. 5	43. 6
Plains:							
North Dakota	22, 814	312, 000	289, 186	1, 222, 810	0	422. 8	------------
South Dakota	52, 895	222, 400	169, 505	1, 013, 110	23, 300	597. 7	44. 0
Nebraska	31, 762	1, 773, 200	1, 141, 438	1, 137, 840	20, 960	99. 6	3. 3
Kansas	96, 248	1, 333, 000	1, 236, 752	237, 020	830	19. 2	. 9
Oklahoma	2, 237	127, 400	125, 163	231, 592	600	185. 0	26. 8
Texas	1, 320, 216	2, 307, 400	987, 184	881, 200	624, 300	89. 3	47. 3
Total	2, 126, 172	6, 075, 400	3, 949, 228	4, 723, 572	669, 990	119. 6	31. 5
Total 17 States	19, 431, 367	51, 534, 900	32, 103, 533	13, 210, 416	7, 761, 630	41. 1	39. 9

[1] Census of Agriculture, 1945.
[2] Land Available for Agriculture through Reclamation, National Resources Board, 1936.
[3] Data from Bureau of Reclamation as released through the National Reclamation Association, January 1948.

Estimates of Potentialities

In the West considerably more land with soils suitable for irrigation is available for development than there is water with which to irrigate it. Perhaps the most optimistic statement of over-all irrigation possibilities from the standpoint of irrigable soils appears in the National Resources Board report of 1936 which contains an inventory of land which may be available through reclamation (table 1). This report mentions an ultimate irrigable area of 51,535,000 acres, which exceeds by about 30,000,000 acres the land now irrigated. But much of the irrigation development now proposed for the Missouri Basin east of the 100th meridian was not included. The present Missouri Basin proposals add about 1,800,000 acres to the National Resources Board estimate of the ultimate irrigation potential in the 17 Western States.

The estimate of the National Resources Board was necessarily developed from incomplete information and so is subject to considerable modification through detailed surveys of the water resources and the economic feasibility of irrigation. The Board recognized in its report that the degree to which the ultimate potential will be developed depends upon the water supply. For many streams the development of the full potential cannot be accomplished without a fully coordinated plan for the entire stream basin. In other streams, the first potential areas developed will, when completed, eliminate the other possibilities, because no water will be left for further development.

Potentialities for irrigation development in the West have been frequently reexamined and reappraised in recent years. These reexaminations indicate that the delineations of the National Resources Board were too optimistic in many areas. Under conditions likely to occur in the foreseeable future, not more than one-third to one-half of this further potential is likely to be developed.

The development of the possibilities shown in an inventory of all projects that the Bureau of Reclamation has under construction, or authorized, and under investigation or proposed, would reclaim an acreage equal to about two-fifths of the future possibilities indicated by the National Resources Board (table 1). These proposed projects would further supply needed supplemental water to nearly two-fifths of all land now being irrigated. They would bring in about one-fourth of the National Resources Board indicated potential in the Pacific States, about a third in the Mountain States, and somewhat more than this indicated potential in the Plains States. In Oklahoma, North Dakota, and South Dakota these proposals of the Bureau of Reclamation exceed the estimated potential by the National Resources Board from nearly two to six times. The land proposed for irrigation in the Missouri Valley is a substantial part of the total covered by all the proposed projects. At the time the National Resources Board made its survey of potential reclamation the areas in the subhumid sections of North and South Dakota were not perceived as susceptible of irrigation.

For the Missouri Basin as a whole the current proposals of the Bureau of Reclamation for new projects just about equal the ultimate irrigable area as indicated by the National Resources Board. For the Central Valley of California these proposals cover about one-half the indicated ultimate area. In the Columbia River Basin the proposals are about 70 percent of the ultimate, and in the Rio Grande Basin the Bureau of Reclamation's inventory of proposals exceeds the National Resources Board indicated potential by about 50 percent.

A broad picture of the present extent of irrigation development and future possibilities based for the most part on the latest river-basin plans of the Bureau of Reclamation, is shown in the fold-in map (fig. 6). East of the Continental Divide, with the exception of a few areas in the headwaters of the Missouri River Basin, only a small amount of water is available for new development in those regions where irrigation is now practiced. Farther east, however, in the areas where precipitation is higher, considerable water is available for new development.

The ways in which irrigation might profitably expand in this area—which includes most of the acreage proposed for development in the Missouri Basin as well as some 750,000 to 1,000,000 acres of potentially irrigable land south of the Missouri Basin—is an open question at this time. Adequate experience and research for determining the economic feasibility of irrigating these areas of higher rainfall, is not available.

Review of Proposals

In the Upper Colorado River Basin above Lees Ferry, Ariz., considerable water is available for further development. The difference in the annual discharge in recent years at Lees Ferry, and the amount the upper basin States are obligated by terms of the Colorado Compact to deliver at this point, indicates that there is still a substantial amount of water that could be used in the Upper Colorado Basin. There are a number of proposed projects for this area. Most of them are rather small and nearly all are costly. Acreage of suitable land is a major limitation.

Interests in Colorado have advanced several proposals for transmountain diversions to carry water from the Colorado River, as tributary water into the San Luis Valley and Arkansas Valley. Practically all of the proposed new irrigation in the Rio Grande Valley of New Mexico is contingent upon the development of a transmountain diversion of the San Juan waters.

Many of the proposed developments in the Colorado, San Juan, and Rio Grande Basins are alternative projects; if some are built, others cannot be built. This is especially true of the New Mexico portions of the San Juan and Rio Grande Basins. Virtually no Rio Grande water is available for further development beyond the possibilities of diversion from the Colorado. Little suitable land is available in the Wyoming or Utah parts of the Upper Colorado Basin.

Despite the fact that more than 6 million acre-feet of water have been discharged annually at Yuma, Ariz., in recent years, relatively little water is available for new development in the Lower Colorado Basin. The rights to most of this water not now being used are vested in the upper basin States and in Mexico. The right to the unobligated part is still under discussion by California and Arizona.

Some possibilities for further development exist in the Bonneville Basin. Prospects for further development in the Lahontan Basin are negligible because of the extremely limited water supply. Considerable additional land susceptible to irrigation is indicated on the map of the Columbia River Basin and the Central Valley of California. In these basins are perhaps some of the most feasible possibilities of the entire West. Projects now under construction and authorized for construction by the Bureau of Reclamation in these basins will bring in nearly 2,000,000 acres of new irrigation.

In addition to possible new irrigation developments there is the possibility of some expansion of irrigated acreage in areas already developed and for which facilities to supply water to additional areas now exist. The last census of irrigation, taken in 1940, showed a total irrigated area of 20,395,043 acres in the 17 Western States. Irrigation structures in existence at that time were reported to be capable of irrigating 27,007,568 acres. In other words, only about 75 percent of the land then reported as capable of irrigation was being irrigated.

Much of the land reported as irrigable is so situated with reference to available water or is so occupied by farmsteads and feeding lots that it may never be irrigated. Moreover, in many instances where existing structures may be physically capable of supplying irrigation water to more land, an adequate source of water supply is lacking.

Twenty-five Year View

Some indication of the extent of additional irrigation that might be expected in areas already developed can be obtained from the records of Federal projects in the last 8 years. All of the projects of the Bureau of Reclamation, including the regular, supplemental, and special and Warren Act contractors who received water from Bureau-constructed works in 1939, reported an irrigable acreage not actually irrigated, of 792,000 acres. In 1947 these same projects had so extended irrigation that their irrigable acreage not irrigated was reduced to 608,000 acres—a net reduction of 184,000 acres, or 33 percent. The rate of expansion on other than Federal enterprises has probably not equaled this record of progress.

The limited water supply in the West, combined with the increasing cost of getting the remaining water on the land is the major obstacle to expanding our irrigation agriculture. With government assistance, the expansion of irrigation may be expected to continue at near the current rate for the next quarter century. As irrigation is pushing closer and closer to the maximum limit of available water supply in many areas and because even now some areas are overdeveloped in terms of permanent water supply and may eventually decline, it can reasonably be expected that within the next 25 years an additional 5 to 10 million acres will be newly irrigated. In addition, a major objective in the years ahead will be the "firming up" of areas that now are short of water.

It can be said that with the ever-diminishing supply of water available for irrigation and the mounting complexity and cost of utilizing this water, the West and the Nation are concerned with the direction that any new developments should take. We need to know the possibilities of potential areas having the greatest promise and to see that the most feasible areas are developed first. The rate at which development should proceed should be dictated by the needs of the Nation, especially for those farm products that can be produced advantageously in the irrigated areas of the West.

The era of single-project appraisal in terms of isolated conditions is past. The part that individual areas will play and the effect they will have on a series of areas or projects within an entire river basin is the consideration now, and will be hereafter.

Physical and Climatic Setting of Irrigation Development

DEFINITE limitations are placed on agricultural expansion through irrigation in the West by the diverse physical and climatic conditions. Sunshine and rain, temperature and wind, are climatic elements which there reach extreme proportions. Land relief and character of soils show the same tendencies. All of them have contributed to emphasize the dissimilarity between the natural environment of the West and of the East. The West as a distinct region is grounded in physical conditions.

For the most part, the physical restrictions to settlement and economic development in the West are far more severe than in the East. The western highlands are the roof of the continent. They form a mountain massif more than 1,000 miles wide in the middle latitudes. High plateaus and basins and plains, separated by lower ranges and divides, form the inner belt. This inner belt is parapeted by towering mountain ranges on both the east and the west.

Rainfall distribution conforms to the mountain pattern. Contrasts in elevation frequently produce equally pronounced contrasts in precipitation. Extremes in temperatures are as great as extremes in precipitation. In the northern mountains and plains the winters are severe, whereas in the southern part and on the California coast the winters are mild. Wind injects still further hazards to agricultural production. Winds of high velocity that are dry and hot occur frequently in damaging proportions in the southwestern High Plains and not seldom in all of the Plains region. Crops are sometimes severely damaged; and wind erosion of the soil and dust storms constitute a serious problem.

Extremes in climate contribute both to the riches of the West as an agricultural area and to its problems of maintaining a permanent agriculture. The 17 Western States encompass 4 distinct climatic regions—the subhumid eastern part of the prairie States beginning with North Dakota and extending south through Texas; the semiarid Great Plains; the predominantly arid area comprising a broad belt of mountain, valley, and desert land some 600 miles wide between the western margins of the Great Plains and the Sierra Nevada-Cascade barrier; and the Pacific coastal area with its dry summer climate. Within this arid area are high water-yielding mountains which produce a large part of the supplies for the Upper Missouri, Colorado, Rio Grande, and Columbia Rivers.

The subhumid region is one of unusual natural potentialities well endowed with topography and soil for agricultural use. But drought is its one serious natural handicap.

Variations in the West

The Great Plains are at places humid, at other places desert, and in most areas either subhumid or semiarid. In the latter areas farmers either gamble with great risk on the weather or are provided an assured water supply by irrigation. Normally moisture-laden air from the south curves eastward and does not reach the Great Plains. Most of the warm air that reaches the Plains comes from Mexico and is so dry that it has little water to spill when it is forced up by cold polar air coming from the north. Sometimes, however, moist ocean air goes westward and the Plains get moisture. So the climate of the Plains is one of extremes. One year it will be as wet as Ohio; another year it will be as dry as a desert. Hail and hot winds are severe. Seasonal contrasts are great. The different air masses sweep over the Plains in such succession that it becomes a meteorological battleground.

"Gambling on the weather" is possible in semiarid country, but intensive agriculture in the western arid region must be supported by irrigation or must perish. Nowhere in the United States has climate influenced the patterns of settlement and agriculture more definitely than in this broad region. It has determined the location of settlement, restricted the number of people that the region as a whole can support, and has been primarily responsible for the introduction of irrigation into the Nation's agriculture. Within the arid region there are great extremes, particularly in the availability of moisture. Moist winds from the Pacific are forced up the Sierra Nevada and Cascade Mountains and spill their load of water invariably on the western slopes. Something similar occurs at each successive range eastward. Thus, though the region as a whole may be parched, it is spotted with moist areas. These humid islands are sources of life-giving water for the valleys below. In this region the combination of mountain, valley, and flat desert, makes for abrupt changes in both precipitation and temperature.

The long stretch of mountains reaching from Washington almost to Mexico divides the arid regions to the east from the Pacific coastal belt. The Pacific coast, west of them, forms the strip of country that receives much more rainfall. But this rainfall is peculiar in that it comes mostly in the winter; in the summer this strip of country has little or no precipitation. Thus its climate is the reverse of that in other agricultural regions of the United States. This region is also characterized by mild temperatures in winter and by intense sunshine and frequent high temperatures in summer.

The native plants of the Pacific coast are adapted to its peculiar climate. Trees grow in the more humid areas, and

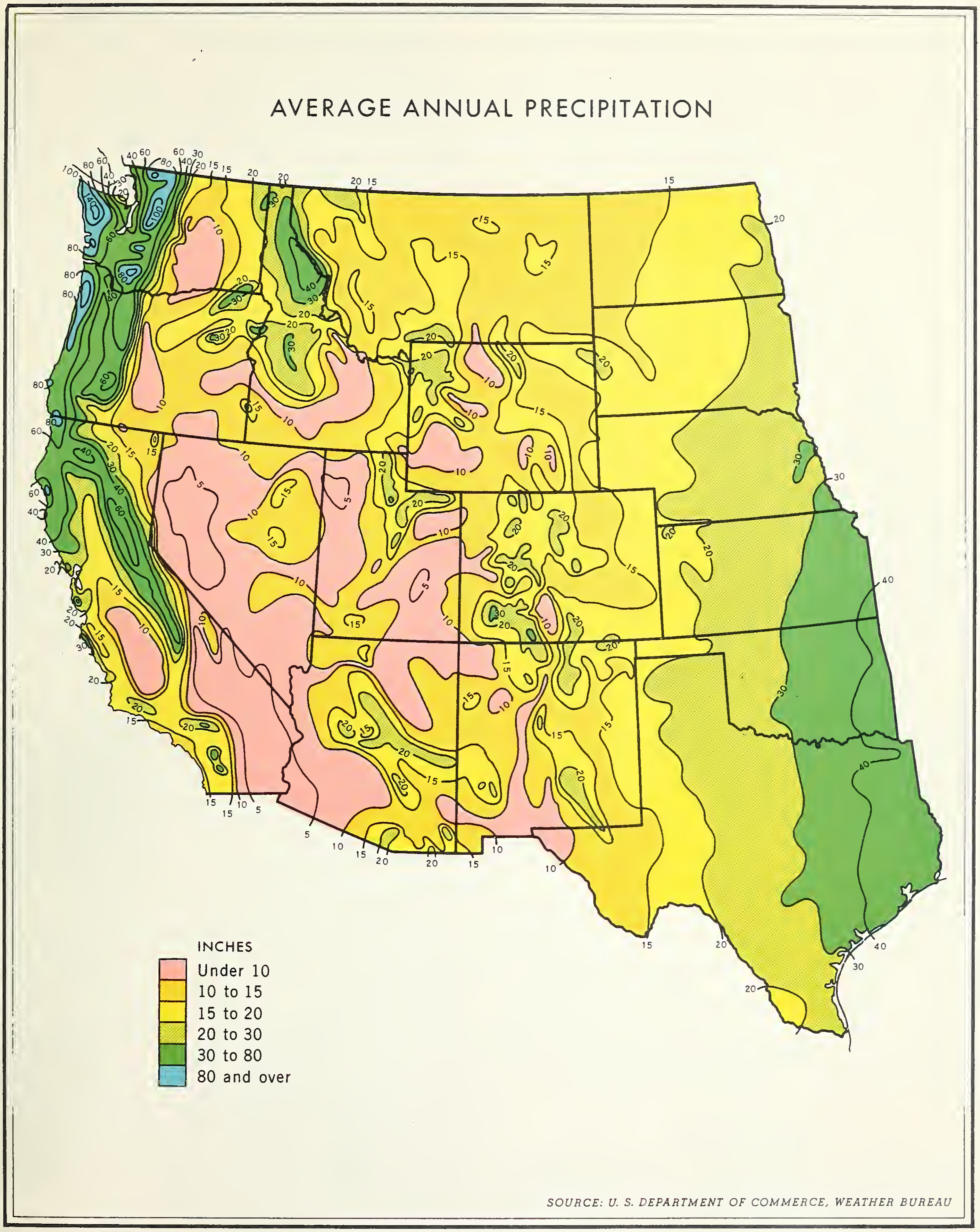

AVERAGE ANNUAL PRECIPITATION
INCHES
Under 10
10 to 15
15 to 20
20 to 30
30 to 80
80 and over
SOURCE: U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

FIGURE 7.

shrubs with deep roots grow in the drier areas. Grasses make their growth in late winter and early spring and ripen in early summer before drought becomes severe. Most of the common cultivated crops, however, are not suited to these conditions. For them irrigation has had to be provided.

Today agriculture in this summer-dry region of the coast is based on the natural advantage of a mild winter and a long growing season. Citrus fruits, the less hardy deciduous fruits, and fresh vegetables are grown in winter for local and distant markets. The rainless summers are admirably adapted to the drying of prunes, raisins, peaches, and apricots. Irrigation does not have exactly the same function it has in truly arid regions; it is supplementary to the winter precipitation. Much of the irrigation water has been provided by pumping directly out of the ground on individual farms. Winter run-off generally flows unused to the sea. Agriculture in the region as a whole depends almost entirely on the extent to which summer droughts are overcome by irrigation.

From the high and dry areas of the West that can be made to produce crops by irrigation, we obtain specialty crops of a nature and variety not obtainable elsewhere and in seasons when our other crops of the kind are not at their best. This set of conditions brings about some of the special advantages of agriculture in the West. Thus we see that some of the economic advantages of the West stem from its climate.

Several measures of climate, when passed in review, show clearly the significance of climate with respect to the agriculture of the West and the need for irrigation to sustain a profitable agriculture there. Some of these climatic elements are here reviewed.

Precipitation

Precipitation takes place when air is cooled enough to release some of its moisture content. This necessary cooling is accomplished, among other ways, when air flows up a land slope. Consequently, there is more precipitation in most of the mountainous parts of the West than in the level plains area where the combinations that bring rainfall occur less frequently. This heavier precipitation in the mountains, much of which comes as snow in the winter, is the source of irrigation water.

Precipitation in the West ranges from desert conditions to rainfall in excess of 100 inches annually (fig. 7). One-eighth of the area of the 17 Western States averages less than 10 inches of precipitation a year. An additional one-fourth of the area has only 10 to 15 inches. Still another fourth has only 15 to 20 inches. A further one-fifth is in the rainfall belt of 20 to 30 inches—which means a deficiency of moisture for many crops and frequently for all crops during vital growing periods. Only 15 percent of the area of the 17 Western States has 30 or more inches of rainfall.

Moisture Regions

Still another way to view the climatic situation of the West and its significance to agriculture is to consider the parts that have enough moisture for plant growth and the parts that have deficient moisture for plant growth. This gives a rational classification of climate, according to the climatologist C. W. Thornthwaite. Dr. Thornthwaite brings into his classification a determination of evaporation from the soil surface and transpiration from plants which, taken together, represent the transport of water from the earth back to the atmosphere—the reverse of precipitation. Precipitation alone, he says, does not tell whether a climate is moist or dry. We must know whether precipitation is greater or less than the water needed for evaporation and transpiration; his findings are given in his classification (fig. 8).

In figure 8 is shown the relation between potential water utilization or water loss and precipitation. Where precipitation is exactly the same as potential loss through evaporation and transpiration, there is neither water deficiency nor water excess, and the climate is neither moist nor dry. The "O" line on the map (fig. 8) approximately divides the United States at the eastern limit of the 17 western States. Thus the 17 western States constitute a region of prevailing water deficiency whereas the States to the east have a prevailing water surplus. On Dr. Thornthwaite's map the moisture indices above "O" show areas of increasing humidity whereas the indices below "O" show areas of aridity.

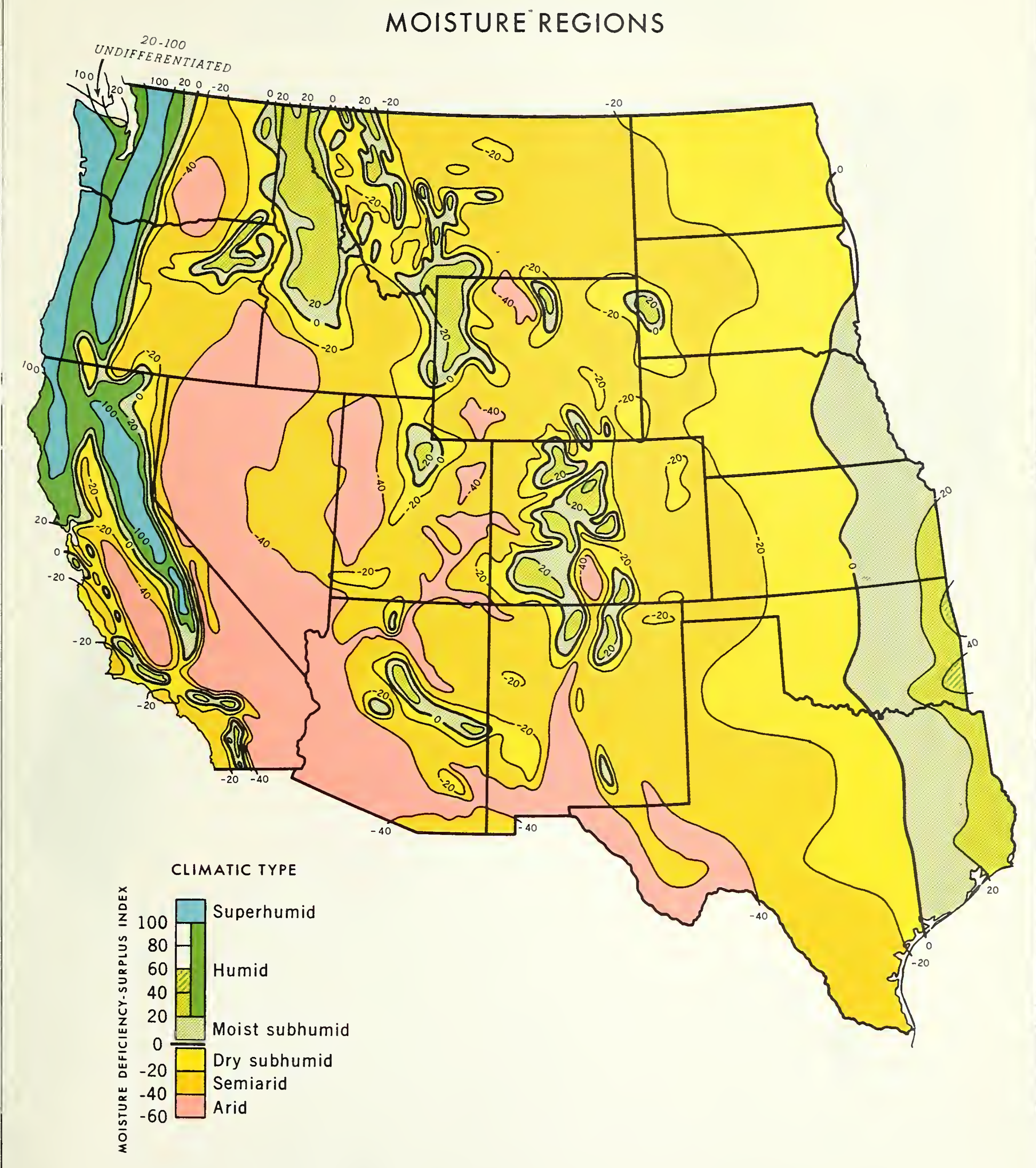
The areas of surplus moisture in the West are high-lighted by the Thornthwaite moisture-region delineations. These are the high mountain areas and the northern part of the Pacific coast. Any realistic water-resource developmental and conservation program must recognize the vital importance of these limited water-surplus-producing areas. The maximum utilization of the water of the West depends upon giving full protection to these sources.

Frequency of Dry Weather

A usual characteristic of a climate is variation. In the West, most of which is subhumid and semiarid and arid, the range in the climate may be from arid to humid from one year to another. These yearly fluctuations of weather create one of the most serious of the climatic risks to agriculture. In some years the amount and seasonal distribution of rainfall in the normally dry climatic areas of the West is entirely adequate for successful agriculture. In other years the rainfall is so meager that crop production is impossible.

In the drier parts, dry years occur persistently year after year. There the farmers do not run the risk of growing crops without irrigation. These parts are confined mostly to the Intermountain region and the Southwest (fig. 9).

The vast Plains country of the West, extending from Canada to Mexico, is not persistently dry. Here many crops can be grown without irrigation, especially wheat, provided proper tillage and water-conservation practices are used. But the farms frequently suffer complete or partial crop failures. The part that irrigation plays in much of this country is to alleviate occasional droughts. Here irrigation increases yields in most years, but it is a form of insurance rather than an absolute essential to crop production.



SOURCE: FROM C. W. THORNTHWAITE, GEOGRAPHICAL REVIEW, JAN. 1948. USED BY PERMISSION.

FIGURE 8.

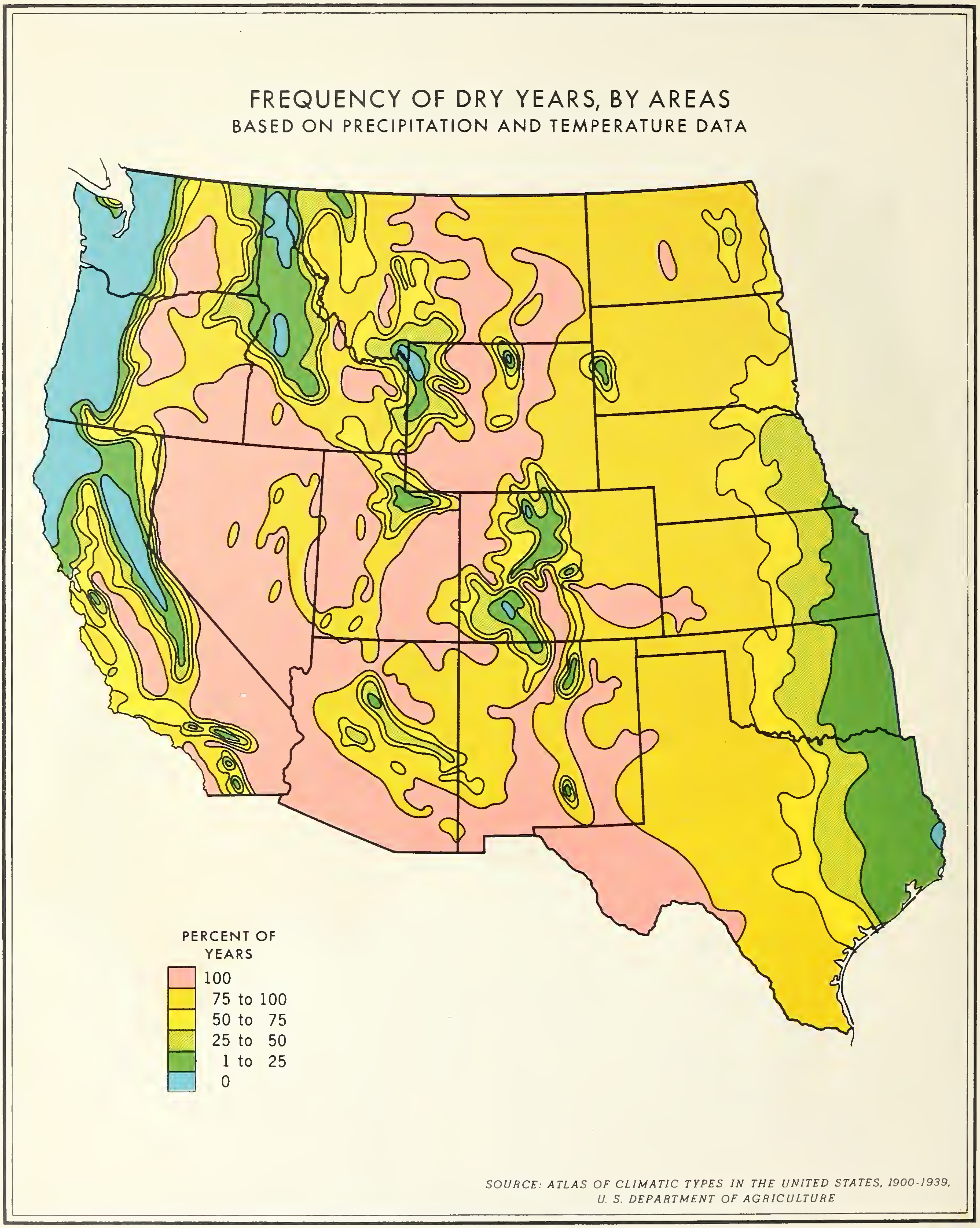
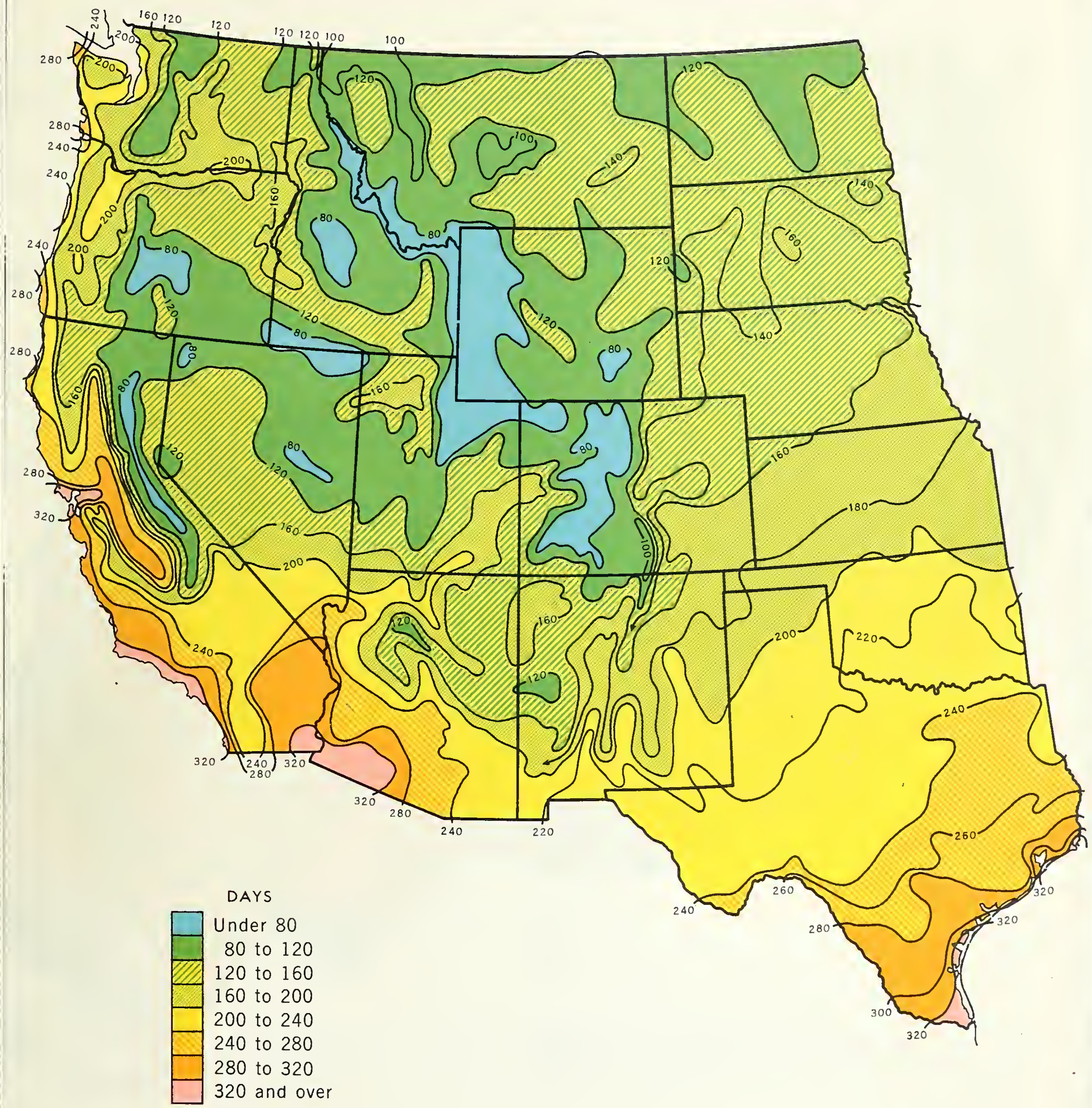

FREQUENCY OF DRY YEARS, BY AREAS
BASED ON PRECIPITATION AND TEMPERATURE DATA
PERCENT OF YEARS
100
75 to 100
50 to 75
25 to 50
1 to 25
0
SOURCE: ATLAS OF CLIMATIC TYPES IN THE UNITED STATES, 1900-1939, U. S. DEPARTMENT OF AGRICULTURE

FIGURE 9.

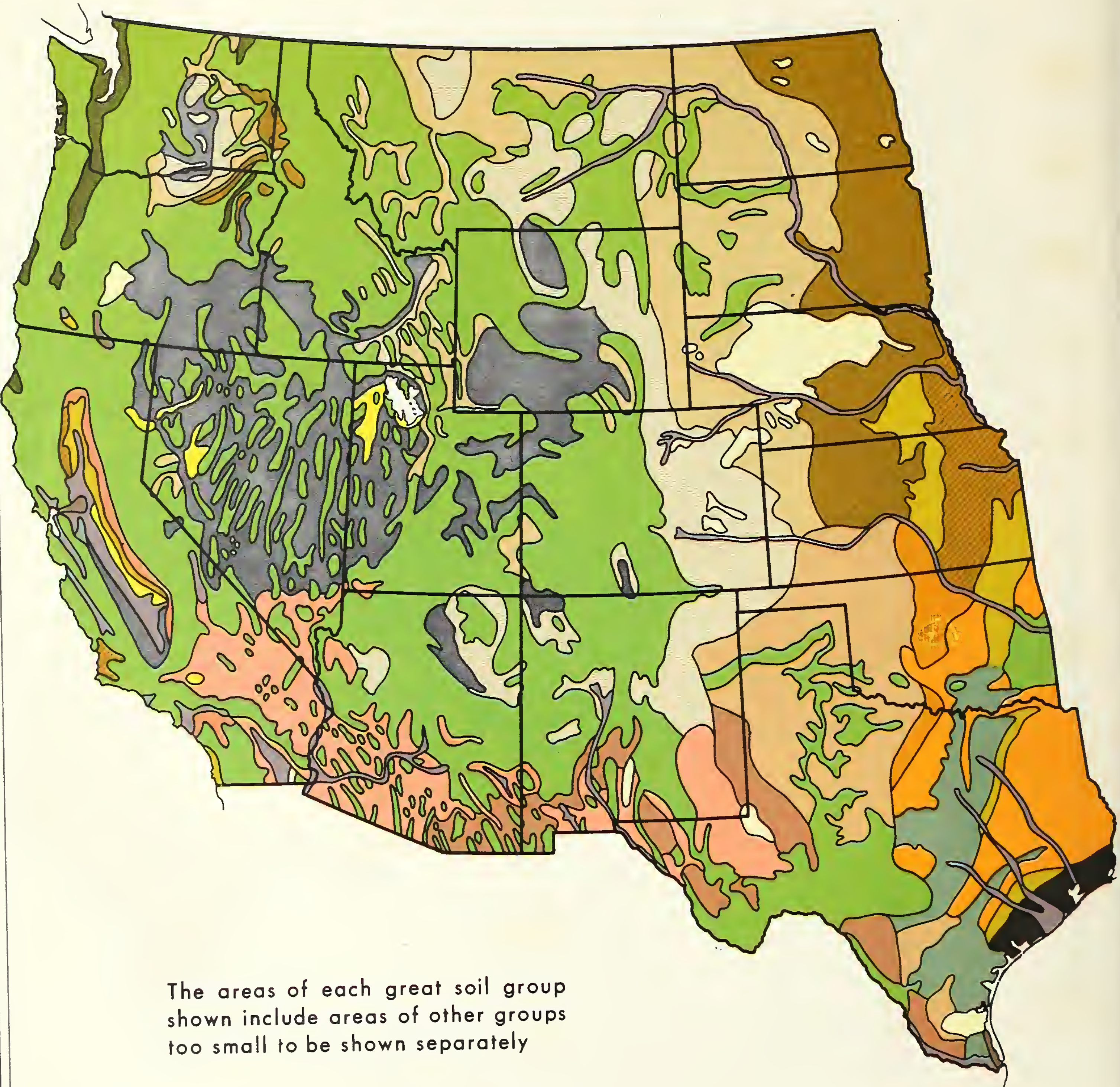
AVERAGE LENGTH OF FROST-FREE SEASON



SOURCE: U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

FIGURE 10.

GREAT SOIL GROU



The areas of each great soil group shown include areas of other groups too small to be shown separately

S OF THE WEST

PRAIRIE SOILS
Very dark brown soils of cool and temperate, relatively humid grasslands.

REDDISH PRAIRIE SOILS
Dark reddish-brown soils of warm temperate, relatively humid grasslands.

CHERNOZEM SOILS
Dark-brown to nearly black soils of cool and temperate, subhumid grasslands.

CHESTNUT SOILS
Dark-brown soils of cool and temperate, subhumid to semiarid grasslands.

REDDISH CHESTNUT SOILS
Dark reddish-brown soils of warm-temperate, semiarid regions under mixed shrub and grass vegetation.

BROWN SOILS
Brown soils of cool and temperate, semiarid grasslands.

REDDISH BROWN SOILS
Reddish-brown soils of warm-temperate to hot, semiarid to arid regions, under mixed shrub and grass vegetation.

NONCALCIC BROWN SOILS
Brown or light reddish-brown soils of warm-temperate, wet-dry, semiarid regions under mixed forest, shrub, and grass vegetation.

PLANOSOLS
Soils with strongly leached surface horizons over claypans on nearly flat land in cool to warm, humid to subhumid regions, under grass or forest vegetation.

RENDZINA SOILS
Dark grayish-brown to black soils developed from soft limy materials in cool to warm, humid to subhumid regions, mostly under grass vegetation.

GRAY-BROWN PODZOLIC SOILS
Grayish-brown leached soils of temperate, humid forested regions.

RED AND YELLOW PODZOLIC SOILS
Red or yellow leached soils of warm-temperate, humid forested regions.

SIEROZEM OR GRAY DESERT SOILS
Gray soils of cool to temperate, arid regions, under shrub and grass vegetation.

RED DESERT SOILS
Light reddish-brown soils of warm-temperate to hot, arid regions, under shrub vegetation.

ALLUVIAL SOILS
Soils developing from recently deposited alluvium that have had little or no modification by processes of soil formation.

SALINE (1) AND ALKALI (2) SOILS
(1) Light-colored soils with high concentration of soluble salts, in subhumid to arid regions under salt-loving plants.
(2) Dark-colored soils with hard prismatic subsoils, usually strongly alkaline, in subhumid or semiarid regions under grass or shrub vegetation.

SANDS (DRY)
Very sandy soils

WET DARK GRASSLAND SOILS
Dark-brown to black soils developed with poor drainage under grasses in humid and subhumid regions.

BOG SOILS
Poorly drained dark peat or muck soils underlain by peat, mostly in humid regions, under swamp or marsh types of vegetation.

MAINLY STEEP OR VERY SHALLOW SOILS
Principal areas only; soils too steep or hilly for irrigation are scattered through most of the other areas.

SOURCE: DIVISION OF SOIL SURVEY, PISAE, U. S. DEPARTMENT OF AGRICULTURE

GREAT SOIL GROUPS OF THE WEST

The areas of each great soil group shown include areas of other groups too small to be shown separately

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FIGURE 11.

Length of Frost-Free Seasons

Our discussion of the modifying effects of climate on agriculture in the West is concluded with a consideration of the differences in the length of frost-free seasons (fig. 10). The growing season of warm-weather crops is restricted by the number of days between the last killing frost in the spring and the first killing frost in the fall.

Along the coast of the Gulf of Mexico and in southern Arizona and California the average growing season exceeds 260 days. This long growing season permits the production of a great many kinds of crops including semitropical fruits and winter vegetables. Farmers there can frequently get two crops from the same field in one season.

In the high altitudes the frost-free seasons average less than 90 days. Some of this high country is likely to have frost any month of the summer. There very little agriculture is possible except wild-hay production and grazing. Much of the northern part of the West has less than 120 days of frost-free growing season. This limits decidedly the selection of crops that can be grown successfully.

The most favorable temperature for plant growth is around 86° F. Temperature limitations vary for different plants. Corn requires up to 5 frost-free months for full growth. Cotton needs from 6 to 7 months free of frost. Barley, wheat, oats, and rye have a hardier resistance to cold but cannot be grown successfully in areas of excessively high temperature. Sorghums can stand considerable really hot weather. Different varieties of all plants react to temperatures in different ways. Much progress has been made in plant breeding and selection of early-maturing varieties, particularly of corn.

Topography

More than 60 percent of the country west of the Great Plains is too steep or mountainous for practicable irrigation. Nevertheless the mountains of the West are as important to irrigated farming as the valleys where the water is used, for when they cool the winds and cause them to deposit their moisture as rain or snow, they collect and store moisture for irrigation. Steep slopes are found not only in the mountains but in many lower-lying areas that are cut by a network of canyons and arroyos. The Great Plains lack the extreme relief of the mountains. But even here extensive areas are so thoroughly broken and dissected that crop farming is virtually impossible.

Topography limits irrigation not only through the influence of steep slopes that make cultivation impracticable but also by imposing such barriers as high mountains or deep canyons between the sources of water supply and the land that can be productive for crops. Great engineering works are sometimes used to overcome such barriers, for example, water from the Colorado River is brought through huge tunnels to irrigate lands in the Great Plains or Great Basin.

Gentle and uniform slopes are most favorable for irrigation. Small surface irregularities are usually removed by leveling to permit uniform distribution of water to all parts of a field. On some soils, leveling off the knolls and ridges may expose unproductive subsoils or substrata of cobbles, gravel, or caliche. On land that is too rolling, leveling is likely to be impracticable; overhead irrigation may be the only means by which water can be uniformly distributed. In this event, more cover crops and other measures are needed to protect the soil.

At the other extreme of topography, land that is nearly flat may limit irrigation by making drainage difficult. If land has too little fall to permit adequate drainage, the soil may become waterlogged, under irrigation. This may result in accumulation of harmful salts in the soil as the water evaporates. Land in the bottom of depressions that do not have natural drainage outlets may not be readily drained and so may be unsuited to irrigation.

Soils

West of the Great Plains a high percentage of the soils occurs on slopes too steep to cultivate. A large part of the soils on mountains and in dissected parts of valleys and basins is too shallow, as well as too steep, for crop growth. Shallow soils occur also in less steep areas, as on some of the high plateaus and in extensive lava beds. In the many intermountain basins and valleys, however, there is a large total area of deep, gently sloping soils that are very productive. The Great Plains rather generally have broad areas of deep gently sloping, productive soils, although steep and shallow soils are widespread.

Deep sands are extensive in the Great Plains and are found locally throughout the West. The largest extent of sand is the great territory known as the Nebraska Sand Hills (fig. 11). Deep sands are not usually well suited to irrigation because their high porosity permits water to pass through too quickly; that takes too much water, and plant nutrients are leached away quickly. But deep, porous sands facilitate the recharge of ground water.

Salty soils, particularly soils affected with sodium carbonate, or "black alkali," limit irrigated agriculture in all of the drier parts of the West. Saline and alkali soils occur in flat areas or on seepy slopes where the drainage is poor and water stands on or near the surface in wet periods. Salty soils can be caused by irrigation if inadequate drainage has allowed water to accumulate in low places. Salty soils can be reclaimed only where good artificial drainage is provided. Where certain sodium salts accumulate in large quantities, the soil may become extremely tight or impermeable, difficult to work, and unproductive. Only the largest areas of salty soils are shown on the map (fig. 11). There are thousands of such areas in the West.

Problems of soil drainage under irrigation are not confined to soils with naturally poor drainage or those affected with alkali. There are few areas in which artificial drainage will not be needed if the land is to be irrigated. Irrigation, even of very sandy soils with rapid permeability, may cause waterlogging of adjacent soils through seepage.

Generally speaking, alluvial soils are among the most favorable for irrigation, as they lie well, are generally fertile, and are usually near a water supply. But in many places they suffer from floods. Also, some of them are too sandy, gravelly, or cobbly. Only the larger areas of alluvial soils are shown on the map.

Except on the higher mountains and in the humid area of the Pacific Northwest, the soils west of the 100th meridian have developed under low rainfall. They have not been leached of mineral plant nutrients so much as the soils in places of heavy rainfall. Scarcely any of them need lime. In fact, some of them have too much lime for some crops, especially where the surface soil is thin, either naturally or from erosion or leveling. The Desert and Brown soils, however, have supported too sparse a vegetation to have accumulated much organic matter or nitrogen.

The Prairie, Chernozem, and Chestnut soils of the Great Plains and Palouse grasslands are among our most fertile soils. On the Prairie and Chernozem soils, irrigation only supplements the nearly adequate natural rainfall and must demonstrate its contribution in the form of more stable yields and new crops and new kinds of livestock.

In the far West, the only important nonmountainous areas whose soils have developed under forest are in the humid valleys of western Oregon and Washington. Mainly these occur in the Willamette and Puget Sound Valleys. The soils are only moderately fertile.

The Planosols occur extensively in the eastern Great Plains and the Central Valley of California. They have a tight claypan or hardpan layer in the subsoil. Yields would probably be improved by irrigation, but irrigation would create difficult problems of drainage. Most of this group of soils occurs in humid and subhumid climates where irrigation is not essential for crops.

Rendzinas are dark-colored, productive, grassland soils from limy materials, found mostly in Texas in humid and subhumid climates. Good yields are obtained without irrigation in the more humid parts.

Red-yellow Podzolic soils are confined, in the Western States, to Oklahoma and Texas. They are light-colored and highly leached; they are low to moderate in productivity, but are usually responsive to fertilization. Mostly they occur in humid climates where irrigation is not essential.

The wet dark grassland soils are found primarily in the Texas coastal prairie. They are nearly flat and are irrigated for rice, which must be irrigated even in humid areas.

So little experience has been had with irrigation in the more humid eastern part of the Great Plains that the effect of irrigation on the soils is problematical. Research in pilot irrigated areas is needed there to ascertain the problems likely to be met and the ways to solve them.

Only the main areas of each of the soil groups are shown on the map. Locally, in each of these areas are soils different from those shown on the map, but they are too limited to be delineated here. For example, many acreages of steep or shallow soils occur outside the area shown on the map as having such soil.

Vegetation

The vegetative cover of the lands in the West reflect the influence of its physical environment. Except in the humid parts of Texas and Oklahoma and western Oregon and Washington the forests are confined to the mountains where moisture is available for the growth of trees. On the high plains, shortgrass is the typical vegetation on the heavier soils. Open woodlands of piñon and juniper are found in many of the intermediate areas between the forests and the sagebrush country. A similar position is occupied by the chaparral in the foothill and coastal ranges of the southern part of the Pacific coast. Mesquite, oaks, and cedars, interspersed with shrubs and grasses, comprise the mixed vegetation on the rough land along the lower Pecos and Rio Grande Rivers, and on the Edwards Plateau. Desert shrubs are the dominant vegetation of the intermountain basins. Deserts with barren ground are limited principally to the salt flats on the bottoms of the now extinct lakes. These variations in plant cover, from barren ground to forest, represent an adjustment to the wide range in environmental conditions produced by the interaction of climate, land relief, and soil.

Vegetation influences the supplies of water for irrigation. Well-vegetated watersheds suffer little erosion and retard the rate at which sediment fills irrigation canals and irrigation reservoirs. Well-vegetated land reduces the rates of surface run-off and so helps in reducing flood damage to irrigated crops and irrigation works, and helps to provide a better quality, more even, and reliable supply of water. A well-vegetated surface best assures the retention and improvement of the natural water-storage capacity of the soil mantle.

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Water Supply and Use in the West

MOST of the West has too little precipitation for abundant crop production. The water that provides the basis for maintaining or expanding irrigation and generating power for pumping, and that supplies the industrial, domestic, and everyday needs of the people, has been truly called the lifeblood of the West. In terms of economic feasibility, a large part of the water resources of the West are now developed and in use. The complex structures that are needed to utilize remaining water supplies place a very definite limitation on further development.

Water supplies have been a major influence on the direction and character of western agricultural development. No other physical factor has had a greater part in establishing the present pattern of agricultural production. The importance of proper conservation and management of the limited water resources in our arid regions has long been recognized. But we have failed to control properly and to utilize fully the natural water supplies and this has upset the balance of physical factors required for continued maintenance and maximum utilization of all resources. Even in the subhumid areas of the West the need has become urgent for more adequate water-resource development.

The need of water by growing city and expanding industrial development has outstripped the natural supplies in many communities. Both industry and agriculture have failed to take adequate measures to insure sufficient supplies of water to meet their expanded needs. Some communities have diminished their potential water supplies by permitting pollution to take place. Farming and rangeland practices in many areas have not properly safeguarded the soil surface against the beating action of rains; the rains have washed away the topsoil and reduced the productive capacity of the land. Eroded topsoil has filled stream beds and reduced the capacity of reservoirs. This siltation has also unfavorably altered the natural sustained character of the flows of many streams.

Proper control, storage, and conservative utilization of the water available for use will insure adequate supplies in most basins for present and prospective requirements for many years to come. This is not to say that shortages of water in many minor tributary basins and in a few of our major basins will not continue to be a barrier to further development. The occurrence of a surplus for a major basin as a whole cannot always be utilized in upstream tributary basins. It is true that trans-basin diversions and other works that had not been thought of a few years ago are being constructed. These devices, and others that have proved to have engineering feasibility, will provide water to many areas that have an insufficient natural water supply.

Surface Water Supplies

When considering the water discharged into the sea from our major rivers it cannot be concluded that it represents the total that eventually can be utilized (fig. 12). There are many reasons why optimum use of surface water for irrigation is somewhat less than the total discharge of streams. Much of the total of discharge from western rivers originates in downstream areas where irrigation is not needed to supplement natural precipitation or where the extent of irrigable land is limited. In nearly all of our streams some flow is needed to avoid stagnation, maintain fish and other aquatic life, and minimize the pollution of water supplies used for domestic purposes. In some of our streams sustained flow is needed for power developmental purposes, in others for navigation. Some return flow from irrigated land is needed for leaching out excess accumulations of salt. Moreover, it is seldom economically feasible to provide for complete storage of peak-flood flows on all streams, particularly on minor tributaries.

The flow of several of our rivers is close to being fully utilized. In the great Colorado Basin extending through the desert and semidesert Southwest, there is only limited possibility for further irrigation development. Any that comes will be small in comparison to that now existing. Many desirable adjustments in the use of water from the Colorado River should be made in the future, but these improvements will not add greatly to the irrigated acreage. The Upper Rio Grande offers little further development possibilities. To achieve a higher degree of efficiency in water use in the Rio Grande Valley will require the application of corrective measures and nondamaging land use practices on the watershed as well as improvement in the methods of water application on the irrigated farms.

The North and South Platte Rivers of the upper Platte Basin have run-off inadequate to serve much more land than has already been developed, even if their water supplies are fully conserved and regulated. Transmountain diversions from the western slopes have been constructed to supplement the flow of these streams, and many reservoirs have been created to store flood waters. Moreover, return flows from upper areas are repeatedly reused on land farther downstream. Any further development on these streams is certainly limited to ventures of increasingly higher cost.

Average annual flow from all surface streams in the 17 Western States has been around 350 million acre-feet during recent years. If only half of this water could be brought to the land in the right places, it would be more than enough to irrigate the 50 or more million acres suggested as the ultimate irrigable acreage. But much of this excess surface water occurs where suitable land is not available or where projects are not economically feasible.

In some of the streams, like those of the Columbia River Basin, only a relatively small part of the total discharge can reasonably be expected to be utilized for irrigation. Much of the water now "wasting" to the sea can be utilized for agriculture and for industry but by no means all of it represents the potential that will be economically feasible to develop.

More than half of the total water discharged from western streams flows to the sea from the Columbia River and from the Washington and Oregon coast and Puget Sound tributaries. Much of it accumulates in the heavy rainfall belt near the coast where practicable irrigation possibilities are definitely limited. This Northwest area is one part of the West where the limitation to further irrigation is generally available land, not water.

Another large part of the total discharge from western rivers is accounted for in streams in the eastern humid areas. More than a fourth of the West's usual surface water is discharged from the Missouri, Arkansas, and Red Rivers, and from the Texas streams that flow into the Gulf. Most of these streams head up in the mountain or semiarid areas and flow through semiarid lands, providing water where it is needed and can be used for irrigation. But the bulk of the total flow of these streams originates in the lower humid part of the basins below the points of greatest irrigation needs, or in flash floods on minor tributaries where storage at present is not economically feasible.

Many of the minor streams in the Great Plains do not have enough flow to provide for economical storage for irrigation. They have erratic flows that vary widely from year to year. These flows occur when it rains and so cannot be used for irrigation without resorting to storage.

The water in the main streams of the major rivers of the Plains is virtually the only reliable source of water for irrigation. The James River, for instance, with a large watershed, has enough dependable run-off to irrigate only a small acreage. To develop irrigation in the James River Valley it will be necessary to divert water from the main stem of the Missouri River, as is now proposed.

Variability of Stream Flow

The quantity of water discharged by a stream is continually changing throughout the year, from rainy season to dry, and the quantity of flow during any one season varies from year to year. Variability is characteristic of stream flow as it is of weather. Because of the high variability of flow of most streams, full utilization of surface water is possible only through regulation and control. The average discharge of a stream is only a general indication of the amount of water available, without storage facilities. Even with storage on many streams, the full utilization of the wide fluctuations is not feasible.

All streams differ somewhat in their characteristics of flow; some differ widely. The basic differences in seasonal variability of flows of western streams may be shown by grouping those of similar major characteristics (fig. 13). Considering only major differences, the streams of the West may be viewed in six groups: The intermountain streams, the Pacific coast streams, the southwestern intermountain streams, the Plains streams with little or no base flow, Plains streams with high base flow, and the streams of the Gulf coastal plains.

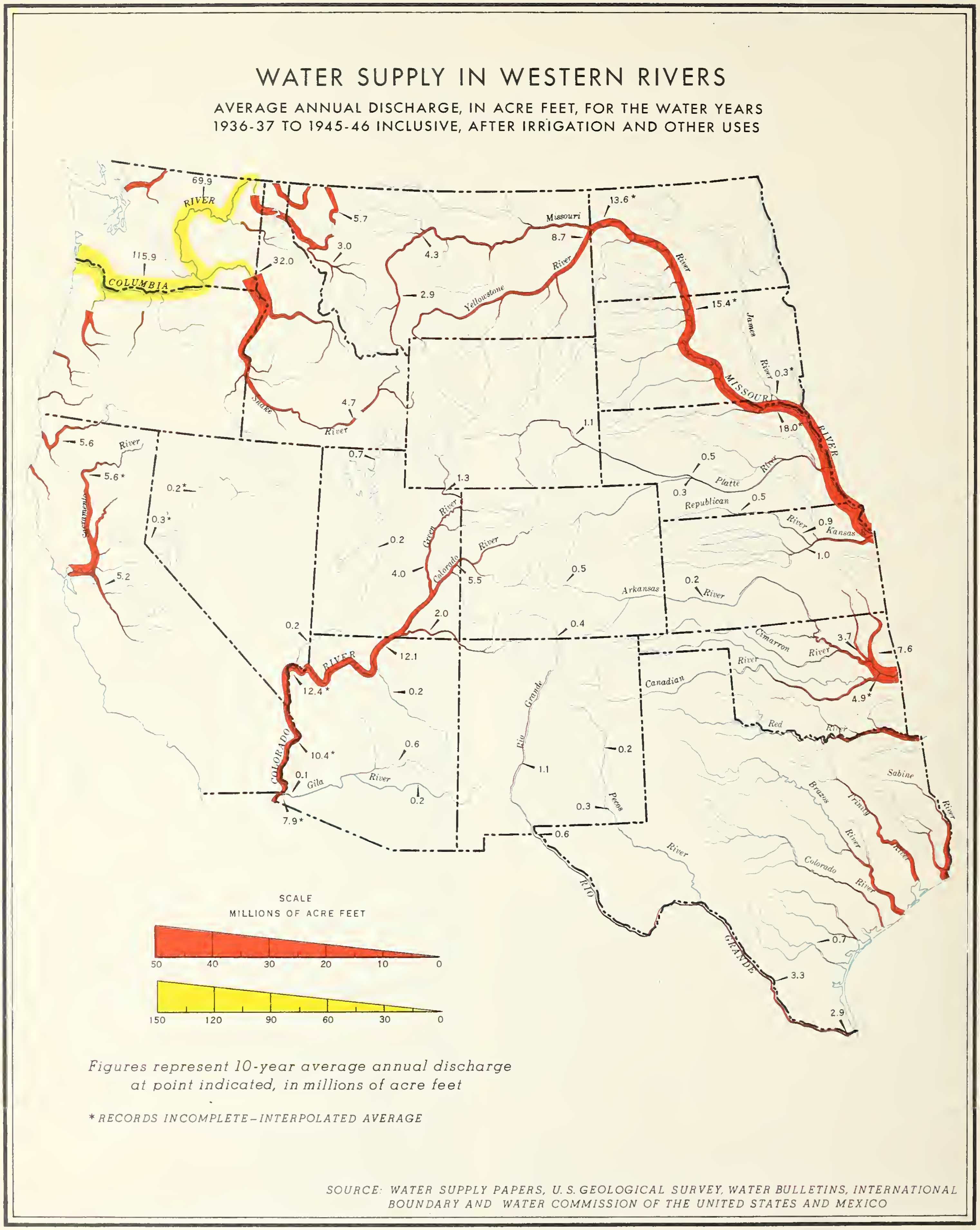
As examples of the characteristics of the intermountain streams, charts are shown for representative stations on the Snake, Yellowstone, San Juan, and Upper Rio Grande Rivers. These rivers that originate in the interior mountain areas are characterized by a high rate of discharge during the period of snow melt, usually in May and June. The rate of flow both before and after the snow-melt period is usually low. The time of peak flow varies somewhat, depending on the time of snow melt. In the Pacific coast and Southwest regions, the melt usually occurs in May, whereas in the higher interior region along the Continental Divide it comes in June and later. The natural flow of these streams is ideal for early-season irrigation. Storage is necessary only for late-season crops, or to provide for fuller utilization of yearly flows.

Stations representative of Pacific coast streams are shown on the south fork of the Skykomish, Umpqua, Trinity, and King Rivers. These streams drain mountain areas but they derive a large part of their flow from rainfall. Therefore these streams often have two periods of peak discharge, one during the winter rainfall and the other during the snow melt. In the Puget Sound area the winter-rainfall peak flow occurs in December, and in the streams farther south it comes in March or April. The maximum snow-melt flow for these streams is in May. Regardless of location, the Pacific coast streams have very low flows during July, August, and September. Storage is required in order to provide irrigation water for the normally dry summers there.

As examples of southwestern intermountain streams, flow charts are shown for the Virgin, Little Colorado, and Gila Rivers. These streams are in areas of scant precipitation and do not carry large volumes of water. They are characterized by two periods of peak discharge, one resulting from early snow melt in March and April, the other resulting from August and September rainfall. These streams are thus unique in their late-summer peak flows.

The streams of the Plains have two distinct types of flows. The streams with little or no base flow are intermittent throughout most of their reaches. They flow in response to precipitation. Peake flows occur during the spring and summer when rainfall is highest. Fall and winter flows are low. Examples shown are the Cannonball and Bad Rivers. In the other distinct class of Plains streams are those with high base flows. These streams are ephemeral in their upper reaches only, and have a high sustained flow, maintained through ground-water discharge, in their lower reaches. The peak flows correspond with the rainy season in the drainage areas. Examples of this type are the Elkhorn and Guadalupe Rivers. Streams with flows of this kind are about ideal for the utilization of water for irrigation, but there are only a few such streams in the West.

The streams of the Gulf coastal plains make up the last group of characteristic flows shown. The streams of this area are strictly rain-fed. They have high rates of discharge



WATER SUPPLY IN WESTERN RIVERS
AVERAGE ANNUAL DISCHARGE, IN ACRE FEET, FOR THE WATER YEARS 1936-37 TO 1945-46 INCLUSIVE, AFTER IRRIGATION AND OTHER USES
COLUMBIA
RIVER
Missouri
River
MISSOURI
RIVER
Yellowstone
River
Snake
River
James
River
Platte
River
Republican
Kansas
River
Arkansas
River
Cimarron
River
Canadian
River
Red
River
Sabine
River
Brazos
Trinity
River
Colorado
River
Rio
Grande
Pecos
River
RIO
GRANDE
Green
River
Colorado
River
COLORADO
RIVER
Gila
River
Sacramento
River
69.9
115.9
32.0
5.7
3.0
4.3
2.9
8.7
13.6 *
15.4 *
0.3 *
18.0 *
4.7
5.6
5.6 *
0.2 *
0.3 *
5.2
0.7
1.3
1.1
0.5
0.3
0.5
0.9
1.0
0.2
0.2
4.0
5.5
0.5
2.0
0.4
0.2
12.1
12.4 *
0.2
3.7
7.6
4.9 *
10.4 *
0.6
0.1
0.2
7.9 *
0.2
1.1
0.3
0.6
0.7
3.3
2.9
SCALE
MILLIONS OF ACRE FEET
50
40
30
20
10
0
150
120
90
60
30
0
Figures represent 10-year average annual discharge at point indicated, in millions of acre feet
* RECORDS INCOMPLETE – INTERPOLATED AVERAGE
SOURCE: WATER SUPPLY PAPERS, U. S. GEOLOGICAL SURVEY, WATER BULLETINS, INTERNATIONAL BOUNDARY AND WATER COMMISSION OF THE UNITED STATES AND MEXICO

FIGURE 12.

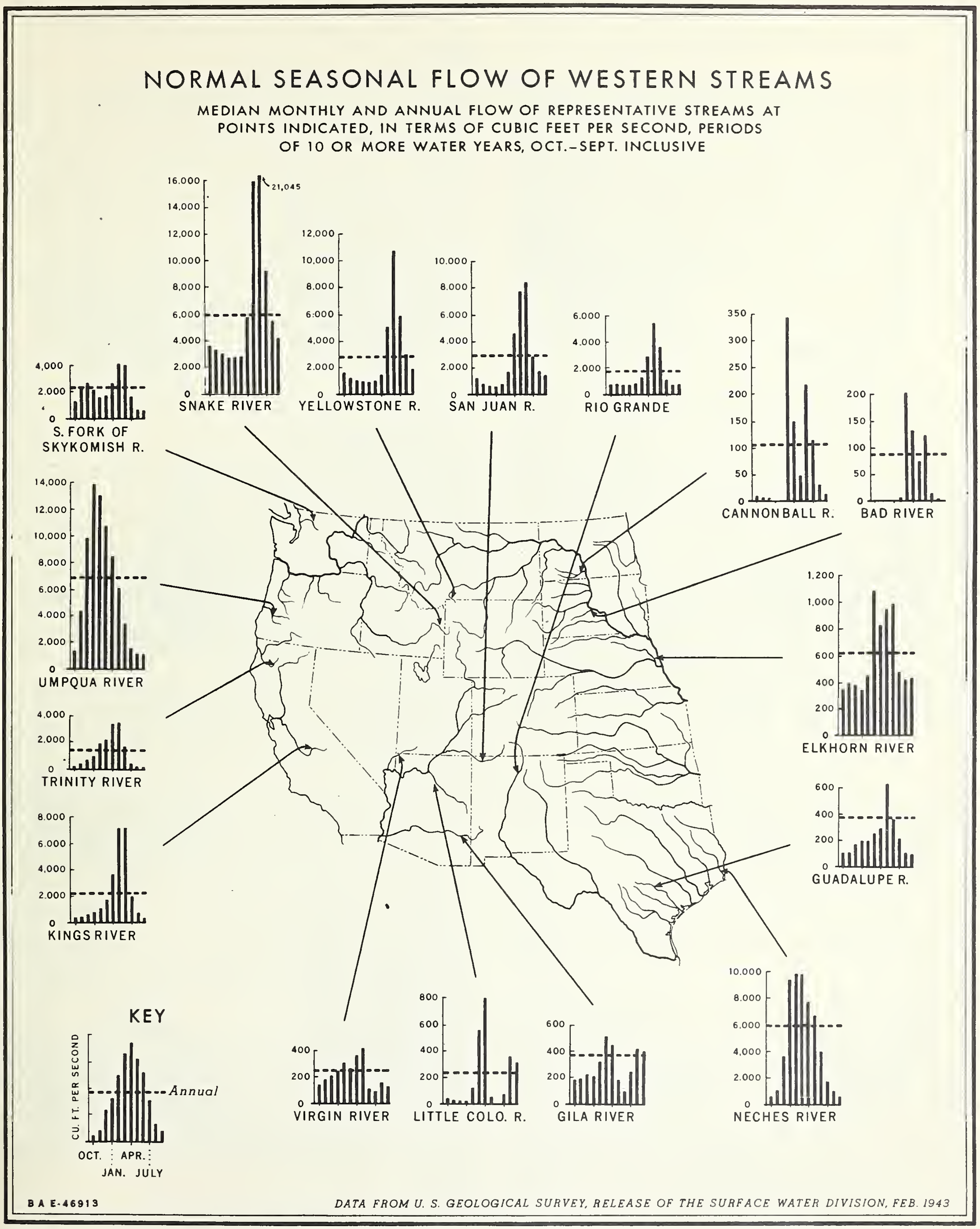

NORMAL SEASONAL FLOW OF WESTERN STREAMS
MEDIAN MONTHLY AND ANNUAL FLOW OF REPRESENTATIVE STREAMS AT POINTS INDICATED, IN TERMS OF CUBIC FEET PER SECOND, PERIODS OF 10 OR MORE WATER YEARS, OCT.-SEPT. INCLUSIVE
SNAKE RIVER
21,045
YELLOWSTONE R.
SAN JUAN R.
RIO GRANDE
CANNONBALL R.
BAD RIVER
S. FORK OF SKYKOMISH R.
UMPQUA RIVER
TRINITY RIVER
KINGS RIVER
ELKHORN RIVER
GUADALUPE R.
VIRGIN RIVER
LITTLE COLO. R.
GILA RIVER
NECHES RIVER
KEY
CU. FT. PER SECOND
Annual
OCT. APR.
JAN. JULY
B A E-46913
DATA FROM U. S. GEOLOGICAL SURVEY, RELEASE OF THE SURFACE WATER DIVISION, FEB. 1943

FIGURE 13.

during the wet winter and spring, and very low flows during the dry months of August, September, October, and November.

Variations of stream flow from year to year have even greater significance in relation to development possibilities than does seasonal variation. Figure 14 shows the variability in annual discharge of selected western rivers. Generally the streams heading up in the mountains have more regular flow than the streams heading in the Plains. Yearly fluctuations are not so great in the flow of the Colorado River, for example, as in the Arkansas River. A stream originating entirely within the Plains, like the Trinity of Texas, in some years has flows that are three times its average annual flow. In dry years the Trinity has had flows only 10 to 30 percent as large as the annual average.

Areas Irrigated by Surface Water

Irrigation farmers rely on two chief sources of water—stream flow or surface water and ground water. In many parts of the West the combination of surface and underground water sources is important in providing irrigation water. Among the exceptions are the Montana and Wyoming areas where surface-water supply is used almost exclusively and the Colorado area west of the Continental Divide, an area where crop production depends almost entirely upon irrigation (fig. 15).

Over the West as a whole more than three-fourths of all irrigated land depends exclusively on stream flow for its water. About three-fifths of the irrigation water used in the Pacific States is obtained from stream flow, and in the Mountain States nearly nine-tenths. Of all the land in the West that is irrigated from surface-water sources, about seven-eighths is supplied by gravity diversion and the remainder is pumped from the streams.

Use of Ground Water

Outstanding areas that depend exclusively on ground water are located in Kansas, Oklahoma, the High Plains, and the Winter Garden and rice areas in Texas (fig. 16).

About 10 percent of the land irrigated in the West obtains the water exclusively from ground-water sources. In the Plains more than one-fifth of the irrigated area gets its primary supply from wells. Nebraska, Kansas, Texas, and Arizona are big users of ground water and both New Mexico and California have large areas dependent upon underground supplies.

Around 10 percent of the western irrigated land receives water from the combination of surface and underground water. Surface waters are used when available; when these sources are dry, well water is pumped. In addition, many irrigators use ground water to supplement their limited rights to surface water.

Sources of water other than streams and underground basins are used to a very limited extent for irrigation. About 1 percent of the land irrigated in the West obtains its water from springs. Some use is made of stored storm water, and city sewage water is utilized to irrigate limited areas.

Nothwithstanding the West's vital dependence on its water supply, it may be said that, to a considerable degree, available resources are used without rigid regard for their limitations. Serious declines in ground-water levels have been caused by an overexpansion of agricultural, industrial, and municipal water uses in many areas. The problem of lowering water tables is especially acute in many parts of the southwestern States where pumping has been heavily relied upon to supply water for irrigation.

Great increase in the use of ground water in recent years is found in the High Plains of Texas, for instance. There the number of wells has increased fourfold in the last 10 years, with a corresponding increase in acres irrigated. In many of the heavily pumped areas, practically all of the water pumped for irrigation and for municipalities is being withdrawn from underground storage, and is not being replaced. Sharp declines of water levels have taken place in the last few years.

Wasteful and inefficient use of surface water seriously threatens many areas and restricts the possibility of development that might otherwise take place with the available stream resources. Excessive losses along the canals prevent the most effective use of much of the water available for productive use throughout the Western States. These losses are mainly due to leakage, to wasteful application of water above that required for efficient crop production especially in the early spring, and to the application of extraordinary quantities of water to areas of excessively porous soils or those requiring frequent and copious flushing to control salinity.

Conservation and judicious husbanding of the West's limited water supply is of vital importance to the agricultural and general welfare of this region and to the Nation as a whole.

Conservation of the water supply of the West requires rectifying a condition of improper or inadequate regulation of ground-water withdrawals. It requires the management of ground-water use by local agencies along sound lines to prevent a continuation of the harmful effects of "every man for himself." It requires the rehabilitation or improvement of irrigation systems that are wasteful in their use of water and the adoption of more efficient practices by many irrigation farmers. It requires the careful selection of new lands to be supplied with water according to their capabilities, in order to assure the greatest benefit from the use of that resource.

Above all, it requires the preservation, improvement, and maintenance of western watershed lands. These lands form the catchment basins for the western water supply; if improperly used, they are the source of sediment that threatens or impairs the value of reservoirs, and reduces the quality of the flood run-off thus permitting the waste of a part of the precipitation that might otherwise augment the usable water supply.

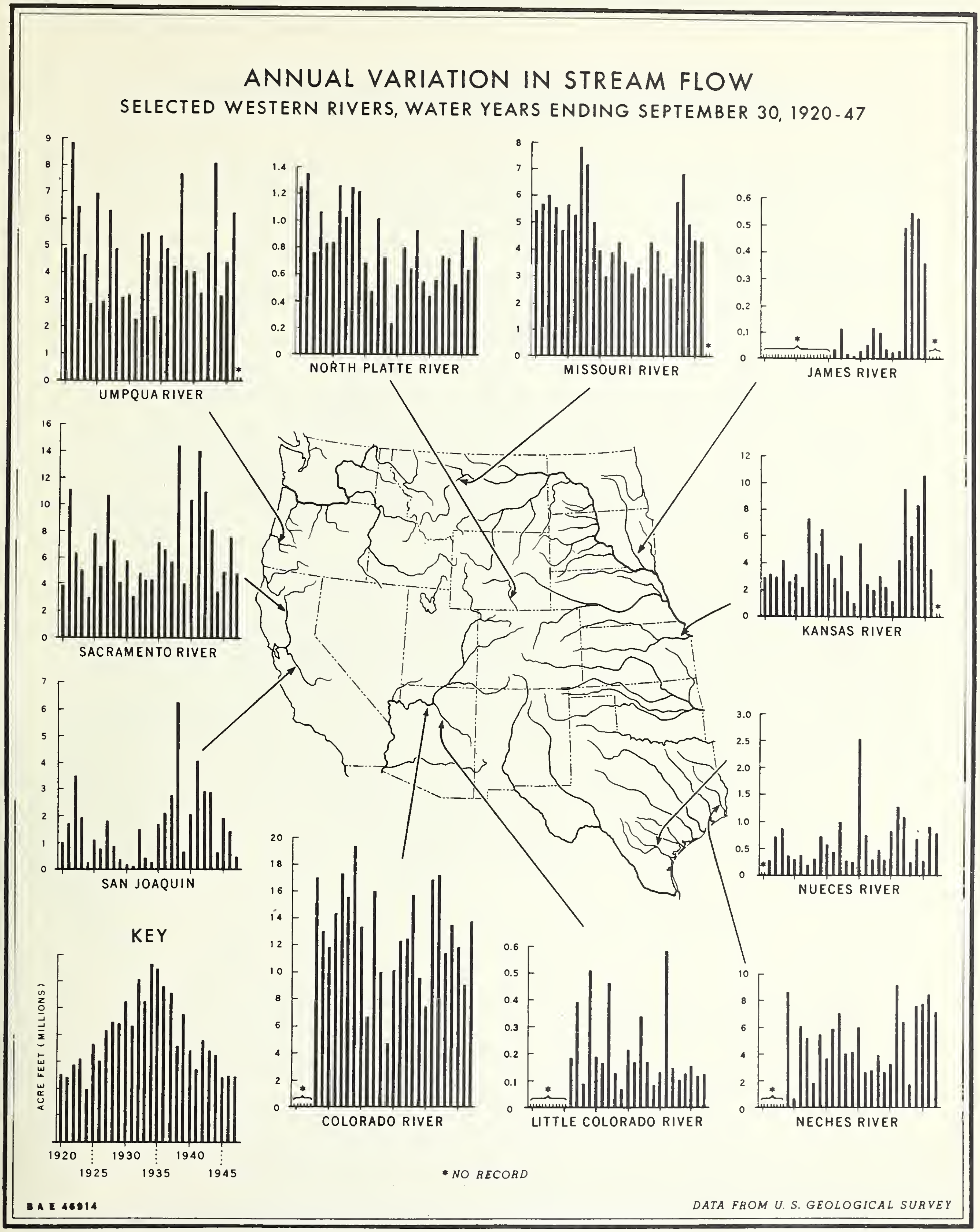

ANNUAL VARIATION IN STREAM FLOW
SELECTED WESTERN RIVERS, WATER YEARS ENDING SEPTEMBER 30, 1920-47
UMPQUA RIVER
NORTH PLATTE RIVER
MISSOURI RIVER
JAMES RIVER
SACRAMENTO RIVER
KANSAS RIVER
SAN JOAQUIN
NUECES RIVER
KEY
ACRE FEET (MILLIONS)
1920
1925
1930
1935
1940
1945
COLORADO RIVER
LITTLE COLORADO RIVER
NECHES RIVER
* NO RECORD
B A E 46914
DATA FROM U. S. GEOLOGICAL SURVEY

FIGURE 14.

MAJOR AREAS IRRIGATED BY SURFACE-WATER

FIGURE 15.

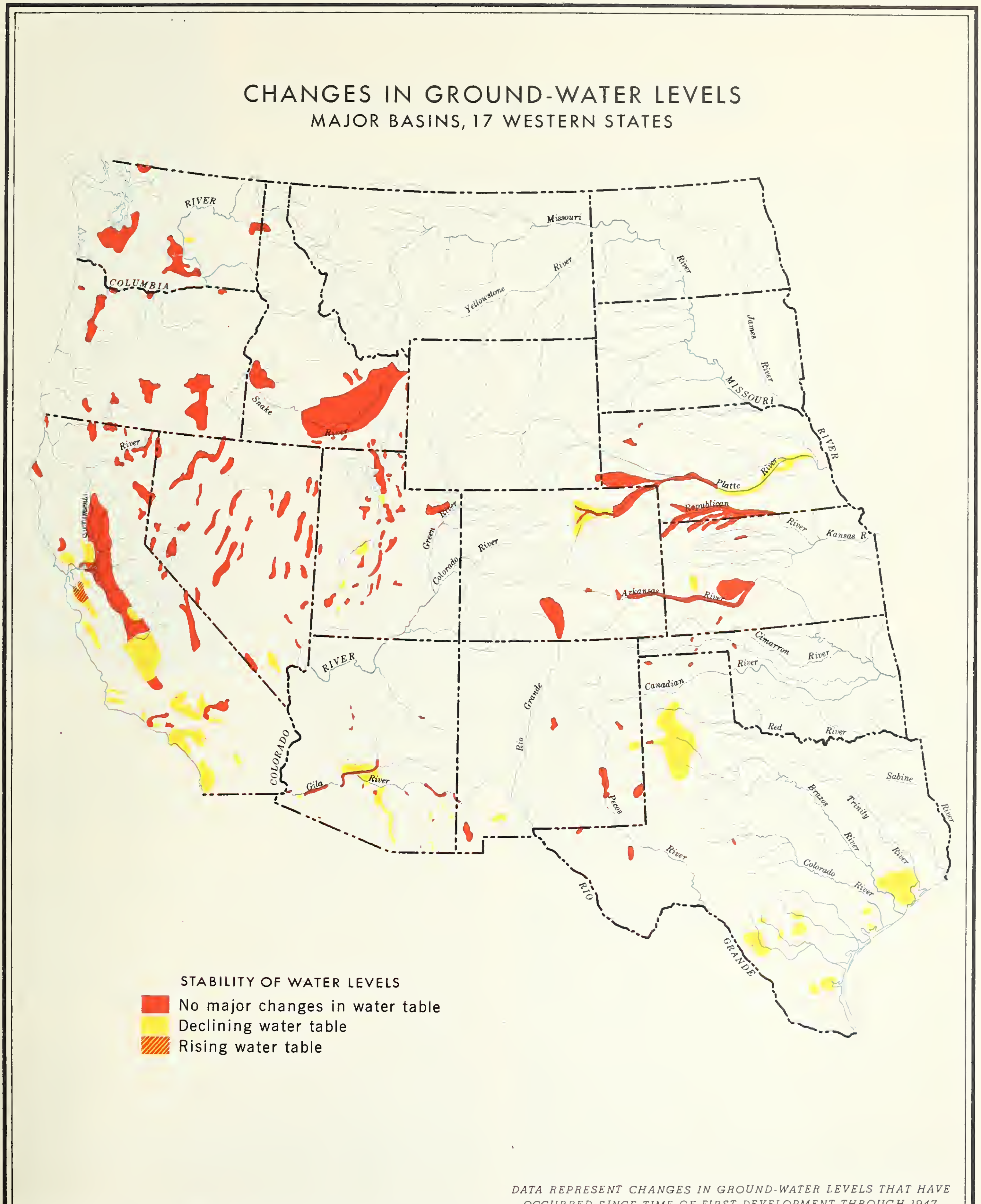


FIGURE 16.

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How Land Is Used in the West

THE 17 Western States comprise 61 percent of the land area of the United States. This is not to say that three-fifths of the Nation's productive land resources are in these Western States. For here are extensive nonarable mountainous areas. Here also are vast areas of semiarid and arid lands that have little or no agricultural resource value except as grazing land or as they can be artificially watered by irrigation.

Land use in the Western States ranges from very little or no use to the highest and most intensive use found anywhere in our country (fig. 17). Transition from the lower to the higher uses is at times imperceptible; sometimes it is accentuated; in places it is abrupt. No definite line marks the end of the desert and the beginning of the area where occasional grazing is found. The boundaries separating scattered woodland from forest are somewhat sharper. Land use in these cases is based on natural distinctions which blend from one into the other. It is vastly different in the higher land-use categories where irrigation and improved cultural practices are carried out. In those categories cultivated land is well defined.

Major Land Uses

The map showing major land uses discloses the spatial distribution of the major uses with reference to drainage and political divisions. Only major uses in significant associations can find expression on a small-scale map of this kind. Although aerial definition is rather generalized, the influence of physical factors on land use can be readily traced.

The largest crop acreage is recorded in the Plains where all three factors—lay of the land, climate, and soils—combine to create favorable conditions for crop production. Exceptions are noted where one or the other of these three factors strongly deviates from the prevailing regional characteristics.

Grazing is the remaining major use in the Plains, where land relief restricts crop use as in the badly dissected belts following the rivers and streams, or in the rough terminal moraines in the northern plains. The Edwards Plateau and its borders mostly fall into the same category. A similar restriction is imposed by the soils in the Sand Hills of Nebraska where crops are confined to wild hay cut in the shallow depressions. A combination of shallow soil and rough surface makes the Flint Hills in Kansas a grazing land. Outstanding in the coastal plains of Texas are the prairies where smooth land and good soil enhance the crop-producing capacity of the farms over those of the surrounding country, but restrict tree growth for natural and economic reasons.

The High Plains constitute a transition zone that reaches from the subhumid in the East to the arid in the West; the Columbia Plateaus in Washington and Oregon have a similar position. These transition areas may be called the semiarid fringe. They are encumbered with a dual handicap of low yields and an uncertainty as to whether any crop at all will mature when droughts occur. Fluctuations in precipitation in this semiarid fringe explain the sharp variation in acreages used for crops from year to year. As land used for dry-farming crops must be smooth, of high quality, and of good water-holding capacity, the land used for it in this zone is highly selective. Numerous disconnected reaches of cropland are found here and there among the adjoining grazing lands.

In the mountainous areas of the West, land use is restricted by topography, soils, and extremes of climate. Nearly all of the areas that appear on the major land use map as forest can be called mountainous country. The main exceptions are the east Texas timberlands and the forested lands of the Puget Sound Basin.

The forested mountains have multiple uses. As humid islands in an arid country their run-off that provides the principal source of water for the lower country; on that account their value as watersheds is highly important. They are the source of a vast timber supply. During the summer season they are used for grazing by the livestock of the ranches. At all times they support big game and other wildlife. The natural scenic wonders found here and there throughout these forested mountains is another national asset. In some places, one or the other of these functions may be restricted or missing and the emphasis may be shifted to others. Grazing is excluded in the dense forests and in most of the national parks. Hunting is not allowed in the wildlife sanctuaries of the national parks. Keeping these many functions of the mountains active and unimpaired is essential to the welfare of the West.

The western deserts are of two distinct types. The Black Rock Desert in Nevada and the Great Salt Lake Desert in Utah are barren glacial lake beds with heavy salt accumulation in the soil. The Mohave Desert is not entirely barren. In comparison of size, the Black Rock and Great Salt Lake Deserts combined seem small beside the Mohave Desert and the adjacent desert country which, taken together, comprise nearly 40,000 square miles in southern California, Nevada, and Arizona.

Between the desert and forests on the one side and the dry-land farming and forests on the other are the vast expanses of plains, basins, lower plateaus, and ranges, with a plant cover of grasses, shrubs, and arid open woods. Most of the woodlands are confined to the levels below the forests, while the shrubs occupy the lower slopes and basins. These three classes of land—the semiarid grassland, the open woodland, and the desert shrub land combined—form the domain of the huge western livestock industry. But another very

MAJOR LAND USE AREAS
WESTERN UNITED STATES

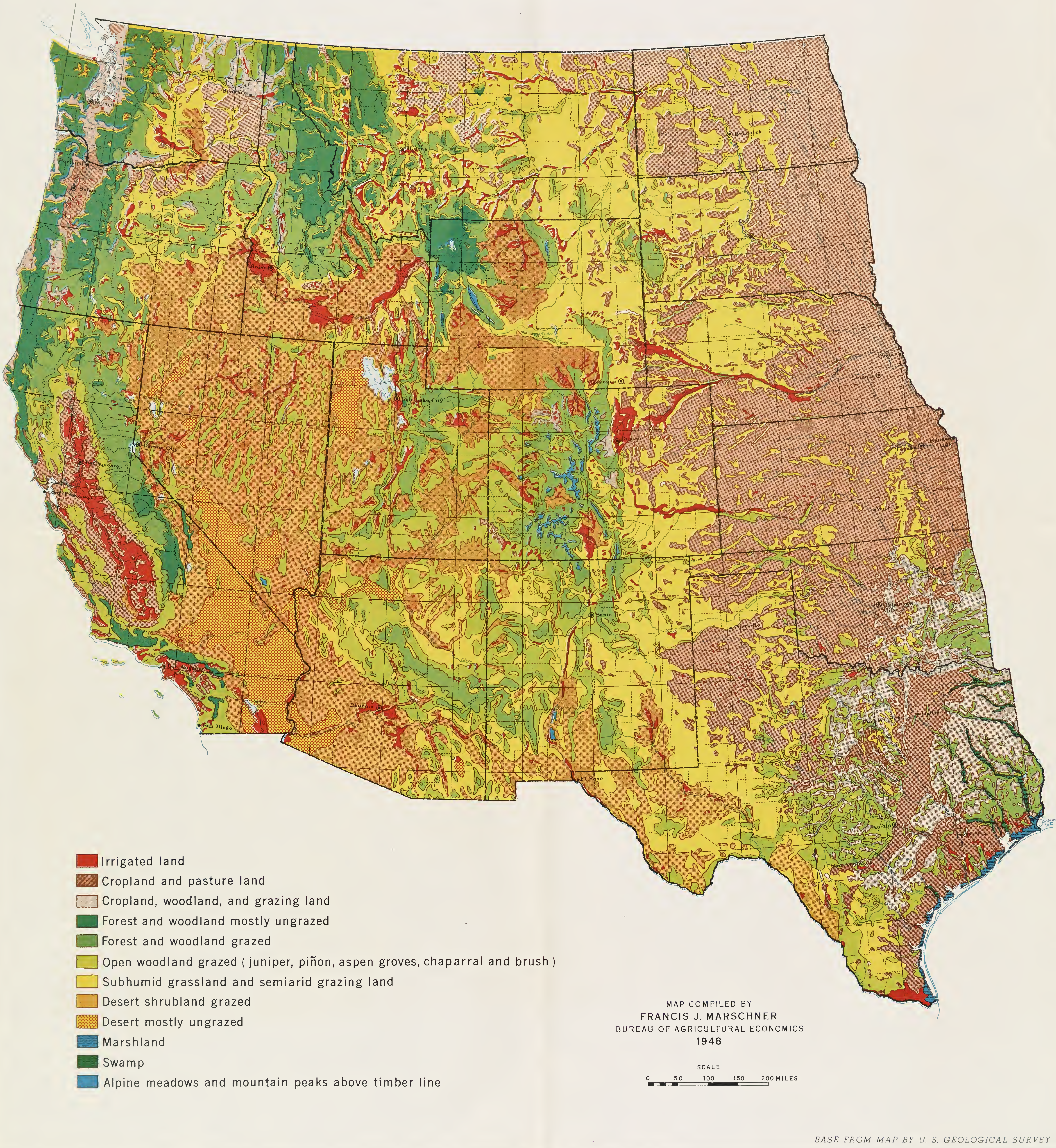


FIGURE 17.

TABLE 2.—*Major uses of land, Western States* [1]

Region	Total land area	Used for crops	Nonforested pasture and range land	Forest land [2]	Nonagricultural uses	Little or no surface use
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*
Pacific States	204, 883	20, 203	60, 025	96, 546	13, 974	14, 135
Mountain States	549, 015	30, 478	341, 122	121, 489	28, 078	27, 848
Plains States	408, 502	137, 735	196, 939	50, 413	13, 485	9, 930
17 Western States	1, 162, 400	188, 416	598, 086	268, 448	55, 537	51, 913

[1] Inventory of Major Land Uses, United States, United States Department of Agriculture. (In Press.)

[2] Exclusive of 7.3 million acres of forest land in parks and military, preserves included in the nonagricultural use classification.

important function of the vegetation on these lands is the maintenance of the watershed soil and water relations.

Grazing practices are associated to some extent with the vegetation types. On the grassland in the southern plains and on much of the woodland and shrub land in the Southwestern States, where the winters are mild and the snow cover is light, grazing is year-long, though supplemental winter feeding is frequently necessary. In the northern mountains and the intermountain region, grazing usually requires the seasonal migration of the livestock to and from the mountains and higher grazing grounds. The grazing season in the mountains may extend to 3 or 4 months in the summer; and in the lower-lying hills, ranges, and basins it may extend from spring to fall or from fall to spring. Some of this lower land may even be suitable for winter grazing but in most places the winter range is inadequate to carry the stock without feed and forage that is derived principally from irrigated land.

Even in the aggregate, in the Mountain and Pacific States the irrigated land is only a little more than 2 percent of the total land, but it is very intensively used and is very productive. From an agricultural viewpoint it makes a very important contribution to the economy of the West. Several of the larger western cities and industrial-centers are associated with irrigated land, drawing supplies from, and selling to irrigation farmers. Many of the smaller irrigated areas in the central and northern parts of the Mountain States furnish the essential supplies of feed-grain crops and hay for winter feeding of the great livestock industry.

Cropland

Only 16 percent of the land of the West is used for crops (table 2). This means that less than one-half of our 400 million acres of cropland lies within the 17 Western States. Moreover, much of the western cropland that is dry-farmed does not have the productive capacity of cropland farther east, especially that in the Corn Belt. But some 20 million acres of irrigated cropland in the West are the most valuable agricultural lands in this country.

It is evident that the value of our western lands for crop production is closely associated with climate and with the availability of water resources. The extent of land used for crops varies considerably with geographic location, which in turn reflects climate.

The six Plains States are rich in cropland resources compared with the 11 far Western States (fig. 18). These six States comprise only one-third of our western lands, but they have nearly three-fourths of the cropland of the West. About one-third of their total area is in cropland and, with the exception of the rough or heavily forested areas found in the Ozark and Ouachita Mountains and in eastern Texas, the bulk of the farm land in the eastern part of the Plains States is available for crops.

Westward across the Great Plains the tillage of land for crops decreases. As the climate becomes drier, more and more of the land is used for pasture and grazing. Dry crop farming becomes increasingly hazardous and farmers depend increasingly upon irrigation for the bulk of their crop farm-

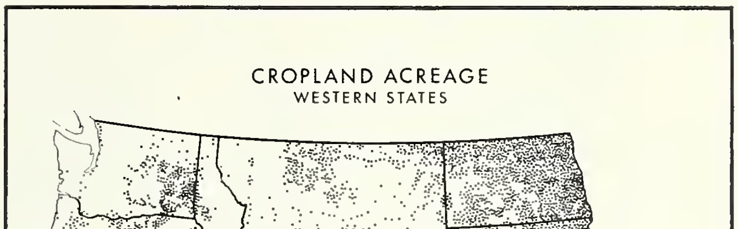
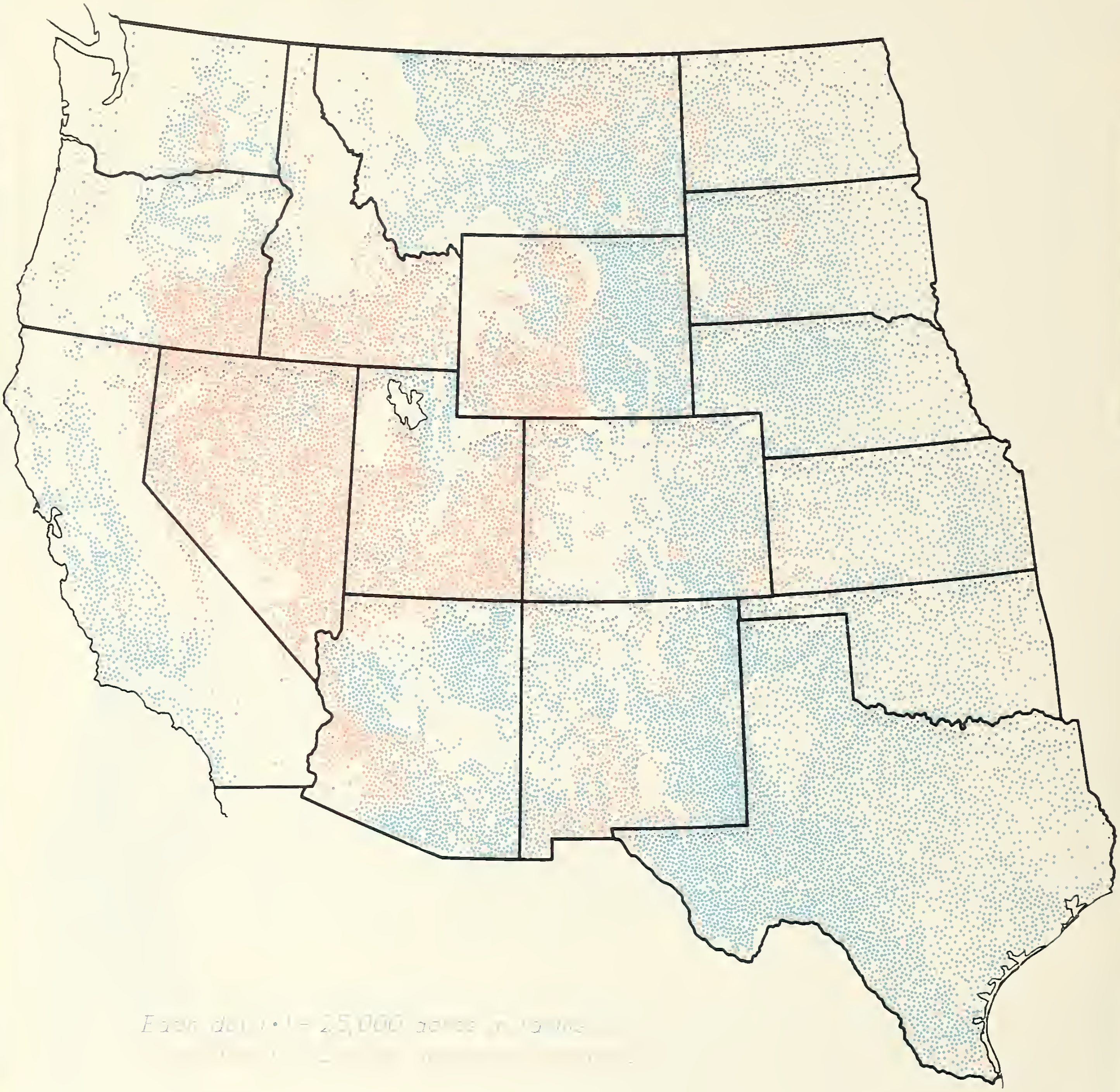


FIGURE 18.

PASTURE LAND NOT FORESTED
WESTERN STATES



TOTAL PASTURE LAND NOT FORESTED, 17 WESTERN STATES–598 MILLION ACRES

BASED MAINLY ON 1945 DATA

ing. In the Mountain States where only one-twentieth of the land is cropland, and in the Pacific States where about one-tenth is cropland, acreage that is used for crops is mostly irrigated. Notable exceptions are the wheat areas of northern Montana and southeastern Washington.

Pasture Land

Half of the land of the West is used for the grazing of livestock. In fact, the bulk of our 700 million acres of nonforested pasture and range land is in the Western States—85 percent of the total. Much of this grazing land has relatively low capacity, but in total it provides the basis for a huge livestock industry. During the last 3 years nearly half of all the cattle and calves and more than two-thirds of the sheep and lambs produced in the United States came from western ranches and farms. In 1947, meat production from cattle and calves alone brought a gross income of 2.4 billion dollars to western farmers and ranchers.

Much of the grassland in the 11 westernmost States is public land, including the grazing land under the Taylor Act, and national forests and monuments. Three-fifths of the land in the Mountain States is pasture or range. In the six Great Plains States and the tier of four States to the west, land is used more extensively for pasture and range than elsewhere in the country (fig. 19). Across these 10 States is a belt of pastured land, so that these States contain more than half of all of the land in the United States that is used solely for grazing. Here is concentrated the bulk of our beef-cattle and sheep production. In 1945–47 these 10 States produced 30 percent of our meat, two-fifths of our cattle and calves, and nearly half of our sheep and lambs.

Topography, soils, and water supplies restrict the possibility of ever irrigating any relatively high proportion of the grasslands in the Great Plains. But a considerable increase in the productive capacity of this region can be brought about by an increase in the production of supplemental grain and forage feeds on irrigated land. Additional irrigated production of reserve feeds in potentially irrigable valleys will contribute materially to the stabilization of the entire livestock industry during excessively dry years.

Forest and Woodland

About one-fourth of the land of the western States is forested, woodland, or brushland. Two great forest regions are in the West—the Rocky Mountains and the one comprising the Pacific forest areas (fig. 20).

The forests of the Rocky Mountains are made up of relatively small timbered tracts, mostly of ponderosa and lodgepole pine. The forested ridges and higher mountain plateaus are interspersed with great treeless stretches—sometimes arid, sometimes rocky.

In the Pacific coast region are the Douglas fir, pines, hemlocks, cedars, and redwoods. This region, with about one-seventh of the commercial forest area of the United States, contains more than half of our total available saw timber.

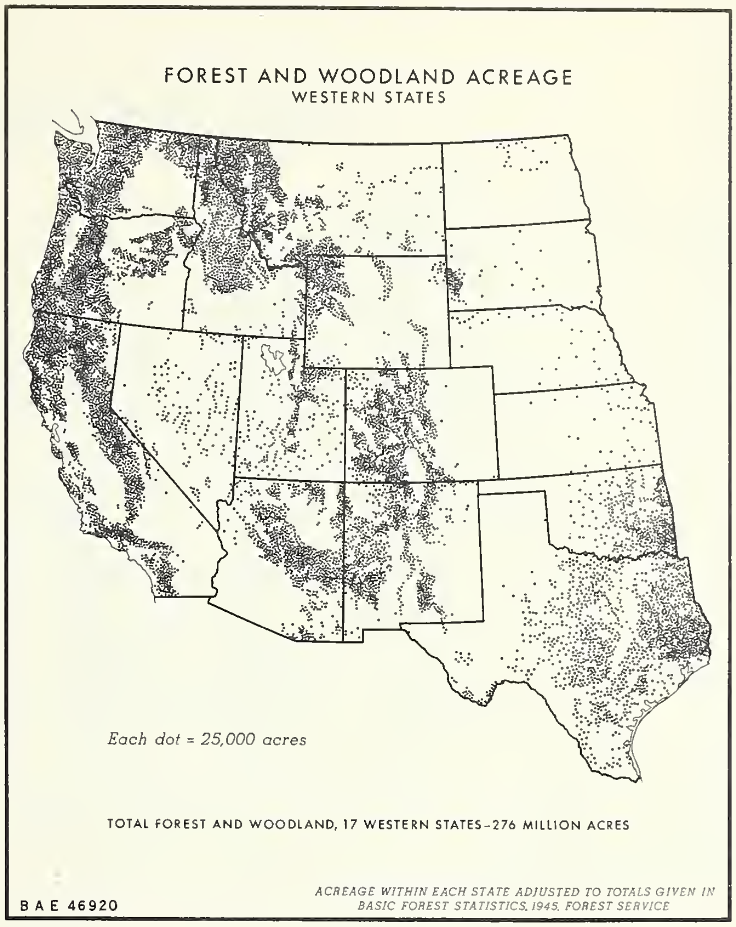


FIGURE 20.

The coastal belt of Oregon and Washington, eastward to the timber line of the Cascade Range, has dense stands of big timber, mostly Douglas fir.

There is a very close relation between the forest and the water resources of the West. The forested mountain areas form the great catchment basins which provide the water for irrigation, as well as for domestic use and for the production of power. The condition and management of these areas are of vital concern to the well-being of the entire West. The forests have great influence on the regulation of run-off and on controlling sediment that might otherwise accumulate in streams and reservoirs. They store the winter snows, help regulate their melt for downstream uses, and increase the quantity of ground water available for irrigation, homes, and farmsteads.

In addition to the areas used for cropland, grazing, and forest, about 5 percent of the total land in the Western States is in sand dunes, rock and desert lands, and marshland. It is of little agricultural value except for what it offers in the way of wildlife, recreation, and the protection of watersheds.

Another 5 percent of the land of the West is used to provide sites for cities and towns, industrial establishments, farm roads, farmsteads, highways, railroads, parks, game refuges, airports, and military installations.

Irrigated Crops in the West

THE growth of irrigation in the West has been in keeping with the rate of the agricultural settlement in this vast region. The first statistical record of irrigation was obtained through the Census of Agriculture in 1889. That census recorded 3,631,000 acres under irrigation. The succeeding censuses show the rapid growth of irrigation during this time of agricultural expansion in the West.

The Censuses of Agriculture are recognized as giving a slight under-enumeration of irrigated lands. But the data from these censuses are considered to be fairly comparable from census period to census period, and so give a good picture of the relative rate of growth of irrigation in the West (fig. 21). The rate of expansion was quite sharp up to about 1920. After that, the rate of further development was slow, for several reasons. The engineering possibilities for easy projects had been pretty much completed. Available ground-water sources in the most arid parts of the West were being fully used. And perhaps the greatest hindrance to further expansion of irrigation was the agricultural depression that began almost immediately following World War I and reached its catastrophic depths in the 1930's.

Gains in Irrigated Area

The defense program calling for increased production, closely preceding World War II, revitalized the efforts of the West in reclamation work. The changed price situation for agricultural commodities then and during the war stimulated irrigation development of different kinds. Results were forthcoming from the stepped-up Federal reclamation program. Development of the use of ground water was expanded greatly in the High Plains of Texas, in Nebraska, and in other areas. Rice acreage, which requires irrigation, was increased. As a consequence of all of these factors, the last 10 years or so has been a period of unusual expansion in irrigation. During the war, according to agricultural census data, our farmers put additional land under irrigation at the rate of about 3 percent of the prewar level per year.

Most of the irrigated land of the United States is in the Mountain and Pacific States (fig. 22). All but about 5 percent of the irrigated land is in the 17 Western States. Large acreages of rice are irrigated in Arkansas and Louisiana, and large acreages of vegetables are irrigated in Florida. California is the top ranking State in acreage irrigated—it has around 5 million acres under irrigation. Colorado has 2.7 million acres of irrigated land and Idaho has somewhat more than 2 million acres. States with more than 1 million acres of irrigated land include Montana, Wyoming, Utah, Oregon, and Texas. The 1940 Census of Irrigation shows somewhat greater acreage in several States than the 1945 Census of Agriculture, the figures of which are used on this map.

Despite the increases in total irrigated acreages, the actual number of farms in the West that have irrigated land has declined in recent years. This is in keeping with the general trend toward fewer and larger farms. Four-fifths or more of all farms in the intermountain and arid parts of the West have irrigated land (fig. 23). In a few counties of the Mountain States, only one-fifth or less of all the farms in each county contain irrigated land. In the humid part of the coast of Washington and Oregon and in a few wheat-producing counties in Washington, Montana, Wyoming, and Colorado, less than 5 percent of all farms have irrigation. In the 1945 Census of Agriculture more of the eastern parts of North and South Dakota, Kansas, and Oklahoma are shown as having no irrigated land than were shown in the 1940 census. This is due in part to the fact that 1944 was generally less dry in these areas than was 1939. It is probable also that fewer of the small irrigated gardens and orchards were counted in the census enumeration in 1945 than in 1940.

Irrigation farming has developed into a distinctive type in most parts of the West. The kinds of crops grown and the cropping rotations practiced on irrigated farms are usually distinctly different from those found on dry-land farms. The cropping practices on irrigated farms are more intensive than those that can be followed on dry western cropland. When irrigation made intensification possible, additional crops were adopted that require greater outlays of labor and capital per acre and that yield higher returns per acre.

Many of the farmers and ranchers use irrigation primarily in the growing of feed crops that are needed in connection with their livestock operations. On other farms, irrigation is the means of growing one or more cash crops—like sugar beets, alfalfa, potatoes, or beans—in addition to feed crops. On still other farms irrigation has been used merely to intensify the type of farming done before irrigation was introduced. But for the most of the major irrigated areas of the West, a distinct type of cash-crop farming, or livestock feeding, or a combination of these, has become established. Most of the truck and fruit farms are wholly dependent upon irrigation. Many irrigated farms produce hay and grains for sale to ranches.

Kinds of Crops Irrigated

Except for rice, food grains are not very important as an irrigated crop (fig. 24). In most counties where irrigation is practiced some irrigated wheat and rye are found. But usually the value of these food grains represents less than 5 percent of the value of all irrigated crops in a county. Of the 13 counties of the West in which irrigated food grains repre-

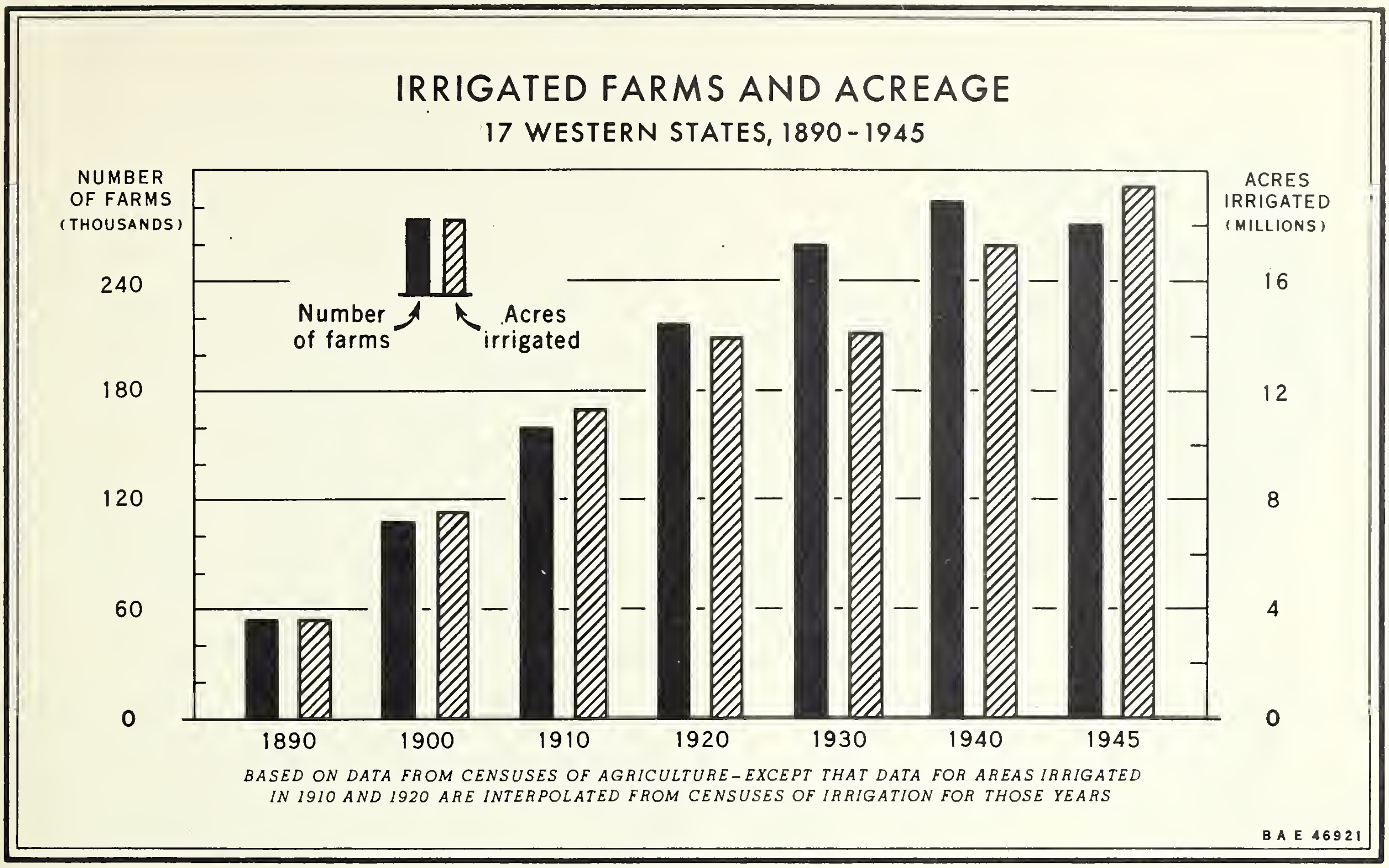


FIGURE 21.

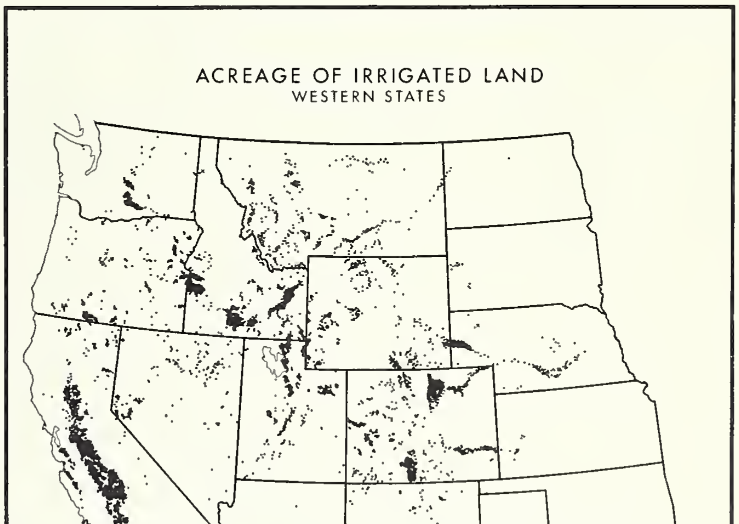


FIGURE 22.

sent as much as three-fifths of the total of the irrigated crops of the county, 10 are in the rice area of southeastern Texas. Then in a few counties in the High Plains of Texas, in the rice area of California, and in the spring-wheat area of northern Montana, food grains rank high as one of the irrigated crops.

In the West feed grains are more extensively irrigated. In most of the Mountain States barley ranks high as an irrigated crop. In the High Plains of Texas sorghum grains are irrigated to a considerable extent, a considerable acreage of corn is irrigated in Nebraska, and in the Northern Plains and Mountain States small acreages of corn are irrigated.

In nearly all areas where irrigation is carried on some hay and forage crops are given water. Hay crops, particularly alfalfa and clover, have high value as rotation crops in building up and maintaining soil fertility, and for many farmers and ranchers who have large livestock operations these irrigated hay crops provide vital winter feed.

In the heavy cash-crop areas—those devoted to the production of fruits, vegetables, cotton, and others—hay production is relatively minor compared with total crop production. But even there, the value of hay crops will frequently run as high as 40 percent of the total value of all crops in those areas. Production of irrigated hay is relatively important in nearly all of the intermountain areas as a result of both physical and economic influences. Hay is one of the best adapted crops in the high altitudes where growing seasons are short. There the nature of the water supply available to many farmers promotes the growing of hay. Those farmers who

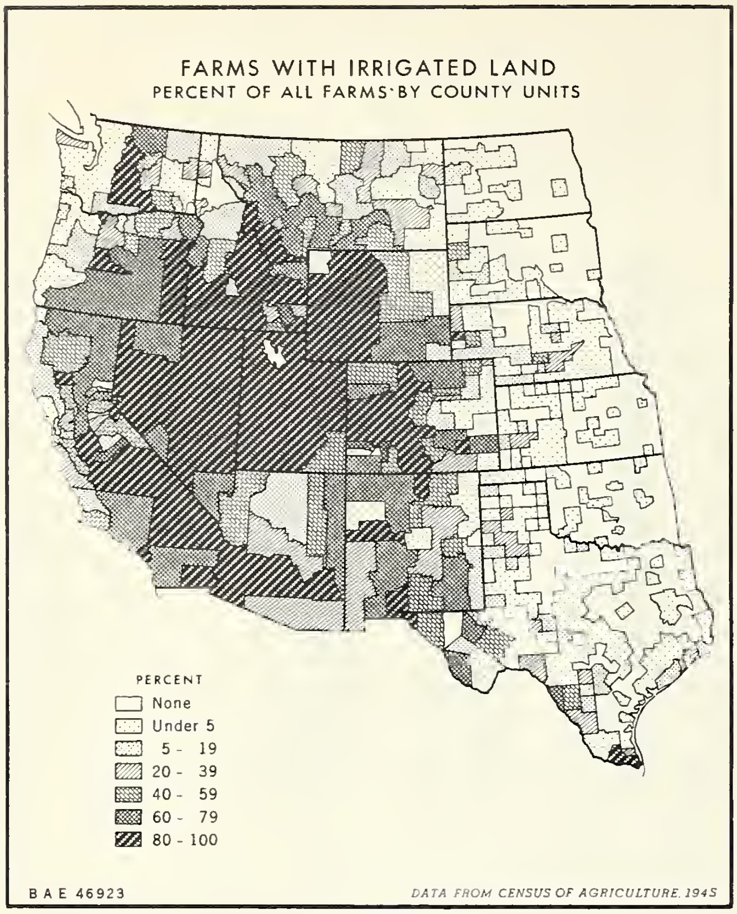


FIGURE 23.

divert water from natural stream flow have enough during the early summer while the streams are flowing but usually do not have water in late summer, and this is one crop that can "get by" without late-season water. An economic factor calling for hay production is the need for it in connection with the livestock-grazing types of farms and ranches which are typical of this region.

Cotton is the outstanding irrigated crop in several counties in Texas, New Mexico, Arizona, and California. In Oklahoma, cotton is the chief irrigated crop, but irrigation is relatively unimportant in this State. All the cotton grown in California and Arizona is irrigated and all grown in New Mexico except for a very small fraction. In western Texas the value of irrigated cotton in any county where irrigation is practiced to any great extent usually represents two-fifths or more of the value of all irrigated crops. Irrigated cotton also represents a considerable proportion of all irrigated agricultural production along the Rio Grande in Texas. But in Texas irrigated cotton represents only a small part of the total crop grown in that State.

The center of the irrigated sugar-beet-growing area is along the North and South Platte Rivers in Wyoming, Colorado, and Nebraska (fig. 25). Large acreages of irrigated sugar beets are also grown in California, Montana, Idaho, and Utah. Sugar beets require cool weather in the fall in order to maximize sucrose percentages. They require abundant moisture throughout the growing season and are distributed generally in the Central and Northern States where adequate irrigation water is available.

Many western farmers prefer sugar beets as a cash crop because they provide a relatively stable and dependable income and because of the byproducts they provide for livestock feeding. The sugar-crop production shown on the map in the counties in the south and east of Texas is mostly in the form of sorgo for sirup.

The irrigated West is especially well adapted to the irrigation of seed crops. The full sun and long continuous dry weather provide almost ideal conditions for the maturing and drying of seeds. In virtually all of the irrigated areas of the West we find some seed production; in some sections seeds are the outstanding crop as in western Idaho and Malheur County, Oregon.

Fruits are irrigated to some extent in nearly all counties where irrigation is found. They are about the only crop irrigated in several of the counties in the subhumid parts. Some of the counties in the Plains States have no irrigation except for an occasional berry patch or orchard. Nearly all of the citrus-fruit production of California, Texas, and Arizona, is irrigated. The irrigation of fruit orchards is especially prevalent in the Pacific Coast States.

Vegetable crops, plus potatoes and beans, represent a substantial part of all irrigated production (fig. 25). In nearly all irrigated counties of the West the value of these crops totals more than 5 percent of the value of all irrigated production in those counties. In a large part of the West vegetables and truck crops represent from one-fifth to two-fifths of the value of total irrigated production. Vegetables as well as fruits are outstanding in many of the counties where but little irrigation is practiced.

Irrigated hops are important in a few counties in the Pacific States. Nearly all of the hops grown in California and Washington are irrigated; in Oregon only about an eighth are irrigated. Considerable acreages of flax are irrigated in California, Montana, and Arizona.

Irrigated Pasture

The 1940 Census of Irrigation showed that in the 17 Western States 12 percent of the irrigated area was pasture land. By individual States the extent of irrigated pasture varies from practically none in North Dakota to 37 percent of the total area irrigated in Nevada. Nearly a fourth of the irrigated land in Oregon is pasture. Washington, Montana, Wyoming, and Utah also have relatively more irrigated pasture than the other Western States.

Irrigation of pasture is not shown in any of the maps but this omission is not meant to indicate that such pasture is not significant to the agricultural economy in many parts of the West. Farmers in increasing numbers are finding it profitable to irrigate their pasture. In this dry region irrigation of pasture is required to get best results with reseeding and with the application of fertilizers. Dairy farmers especially find it advantageous to irrigate pasture in the late summer season to avoid heavy losses in milk production when their pastures would otherwise dry up. The irrigation of pastures by flooding or water spreading is a common practice but for best results some farmers are adopting sprinkler systems. Sprinkler systems make it possible to improve the pastures on rough land that has shallow soils.

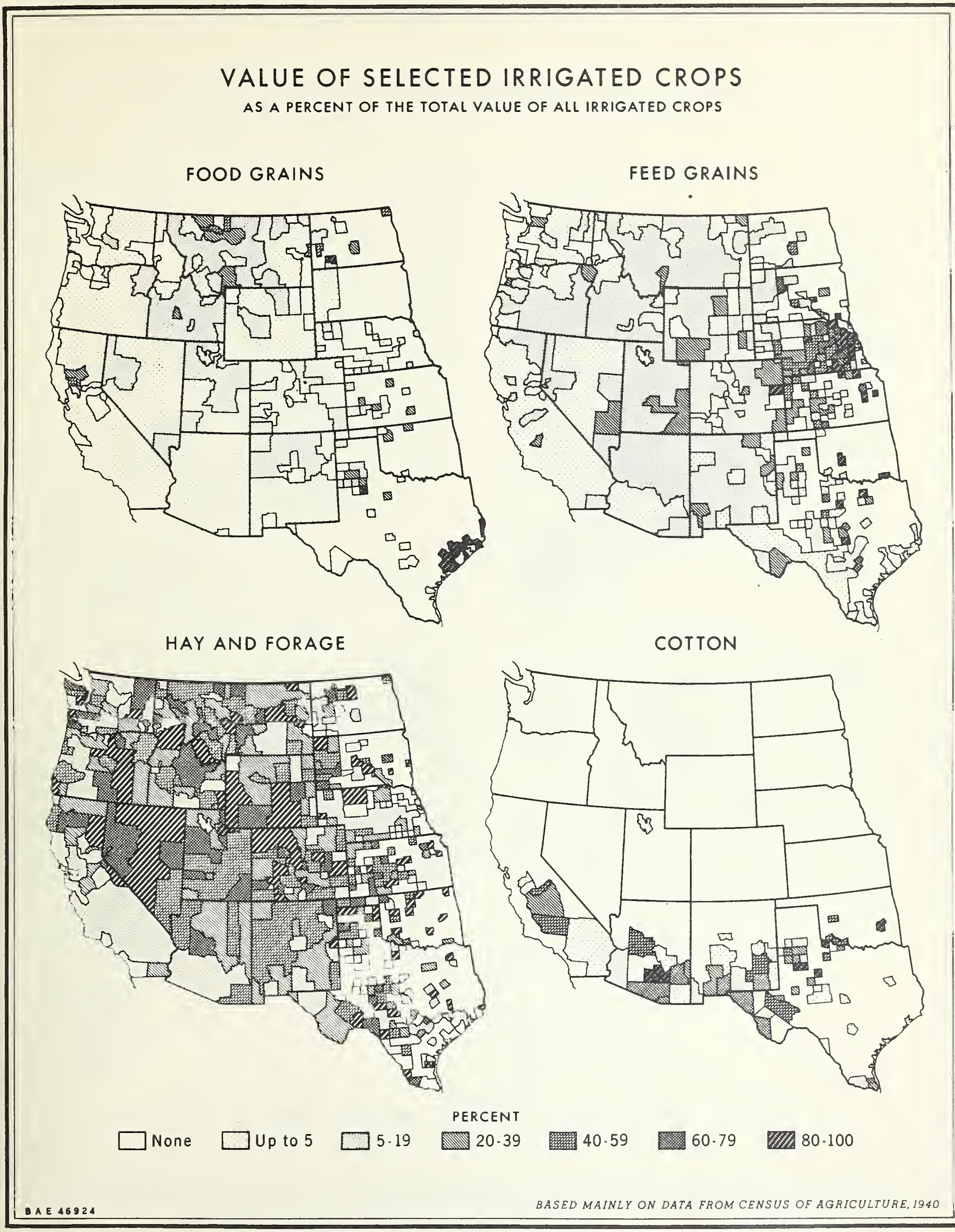

VALUE OF SELECTED IRRIGATED CROPS
AS A PERCENT OF THE TOTAL VALUE OF ALL IRRIGATED CROPS
FOOD GRAINS
FEED GRAINS
HAY AND FORAGE
COTTON
PERCENT
None
Up to 5
5-19
20-39
40-59
60-79
80-100
BAE 46924
BASED MAINLY ON DATA FROM CENSUS OF AGRICULTURE, 1940

FIGURE 24.

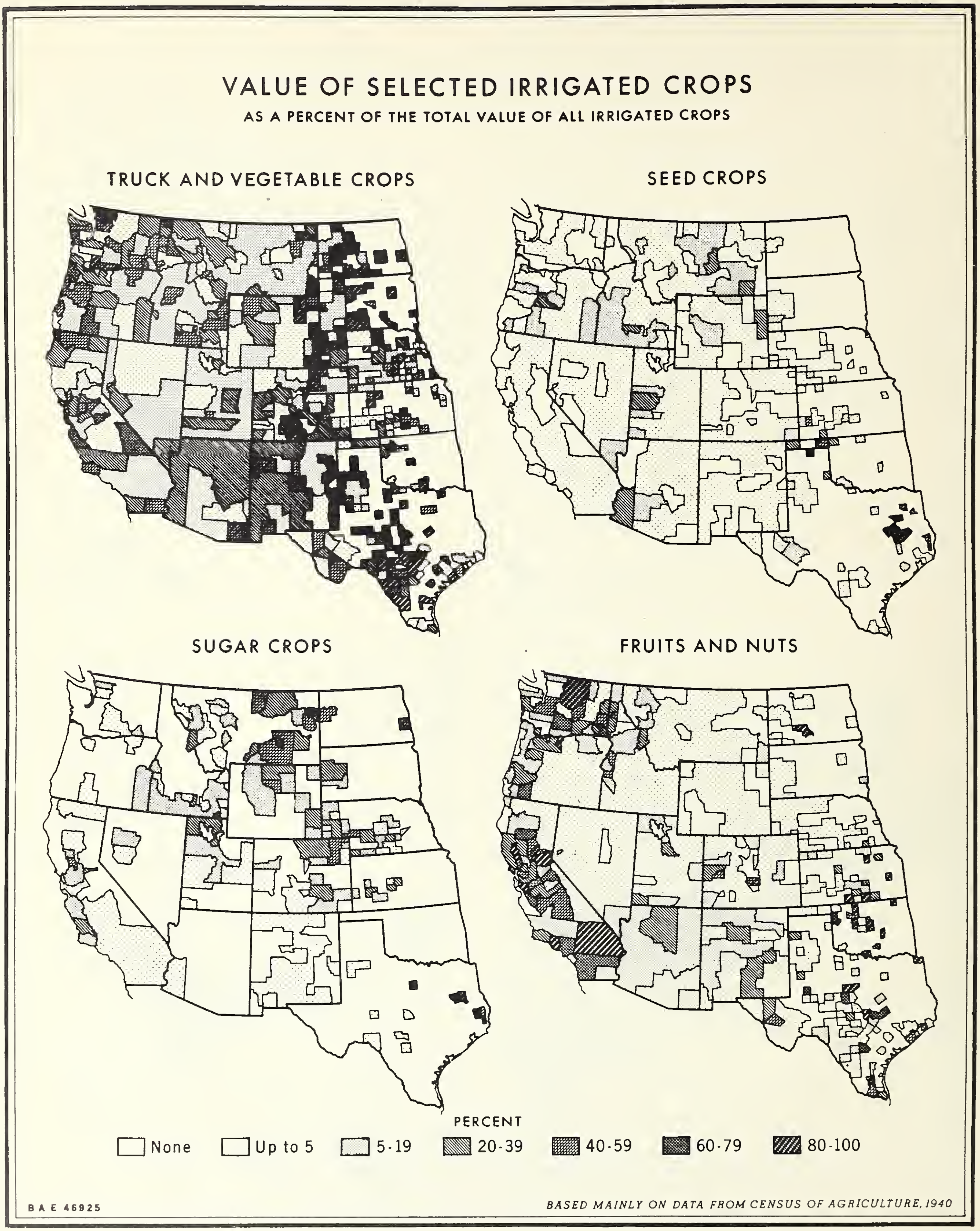

VALUE OF SELECTED IRRIGATED CROPS
AS A PERCENT OF THE TOTAL VALUE OF ALL IRRIGATED CROPS
TRUCK AND VEGETABLE CROPS
SEED CROPS
SUGAR CROPS
FRUITS AND NUTS
PERCENT
None
Up to 5
5-19
20-39
40-59
60-79
80-100
B A E 46925
BASED MAINLY ON DATA FROM CENSUS OF AGRICULTURE, 1940

FIGURE 25.

An Expanding Irrigation Agriculture

GREAT potentialities lie ahead for the West in some further expansion of irrigation and in improved utilization of its water resources for irrigation and other purposes. The nature of irrigation agriculture in the West and the factors that influence and modify its growth have been reviewed. The many factors that must be dealt with if a wise development of the western water resources is to be achieved makes that development a complex job. But it is a job that can be done in such a way that permanent progress is made, if a proper balance between use and supply of water is maintained, and if sustained and rigorous attention is given to essential conservation needs.

Irrigation, irrespective of where it is practiced, as a means of supplementing natural rainfall for food and fiber production is basically an agricultural undertaking. The wise development of the land and water resources of the West through irrigation is of paramount importance to western agriculture and profoundly affects the agricultural and economic structure of the entire Nation.

The ultimate objective of a great dam, reservoir, or diversion works built to serve irrigation is to make good economic farms where there were none before or to make better farms out of existing dry-land farms or ranches by supplying the water that nature fails to supply in order that the type of farm or ranch enterprise can be changed or adjusted to more profitable farming. In its proper perspective, the building of the main structure is an essential but not the paramount element of the undertaking. The final purpose is the improvement of the land and the best use of the water for the welfare of the people who will work with these resources in agricultural pursuits for generations to come. The farms that are created as a result of irrigation projects must be looked upon not merely as a source of security for the repayment of the costs of the great engineering works, but as the foundation for sound agricultural operations and prosperous and contented rural communities.

So far, western irrigation development has been largely financed by private capital. Some 76 percent of the irrigated land in the 17 Western States is served by works constructed wholly by private interests. The Federal Government has constructed works which supply primary water to only 13 percent of the land that is now irrigated and which supply supplemental water to another 11 percent.

But what will be the future trend in western irrigation development? It has been stated earlier that the easy-to-work areas have been developed, that future developments will become more and more complex, and that the extent to which new areas will be irrigated will depend principally upon the degree of participation of the Federal Government.

Significant additions to our western irrigated agriculture will be made as parts of future multiple-purpose undertakings. It is no longer possible to open up any considerable new irrigation acreage by means of project works for which the entire cost can be repaid by irrigation interests. Future projects will mostly be designed and constructed to deal with irrigation, power, navigation, wildlife, and domestic water supply. Good public policy requires that, in the over-all, these projects shall be physically and economically sound and that the benefits from each separate feature shall exceed the added cost of providing that feature. This will require close scrutiny of each of the purposes to be served by each proposed project and of the possibilities and limitations connected with each.

The general public has a major stake in the future health and expansion of the Nation's irrigation agriculture. The way in which our remaining water resources are conserved and used directly affects the agriculture of local areas and of the Nation as a whole. The development and use of these water resources for irrigation purposes is basically an agricultural undertaking. We can have but one national agricultural plant into which all production segments must be integrated. The United States Department of Agriculture has major responsibilities in connection with the welfare and further development of that segment of the agricultural plant that is supported by irrigation. The policy of the Department is to encourage and aid in the development of any feasible irrigation project that will contribute toward attaining a more efficient agriculture. The wise development of our limited remaining frontiers must be the goal of all who are interested in the uses which our available water and land resources can be made to serve. That goal must be sought with increasing vigor.

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