countered as the result of the greater quantities of straw produced and more difficult weed control. Stubble mulch reduces wheat yields more in areas of high precipitation.

Rotations that include a sod crop have been adopted (at least partly) by most farmers in the higher rainfall sections of the eastern Palouse and Blue Mountain areas and in the Moscow Mountain foothills and Nez Perce-Grangeville Plateau areas. Conservation rotations have been used very little in the rest of the region.

Utilization of crop residues by various methods has been extensively adopted; many farmers used to burn their straw. The large increase in the use of nitrogen fertilizer, plus the utilization of residues, has increased crop production and strengthened the program to maintain organic matter.

Stripcropping has been adopted to a limited extent, mostly in areas that have gentle slopes.

Scientific findings and experience of farmers have indicated that more effective conservation and efficient crop production can be achieved in the Pacific Northwest wheat region.

Erosion losses can be reduced substantially, where moisture conditions permit, by substituting rotation systems of cropping for summer fallow. Less tillage also would reduce runoff and erosion.

A wider adoption of stubble mulch tillage in areas of higher precipitation would reduce erosion losses sharply. Further improvements in tillage, fertilization, and weed control are necessary in order that the stubble mulching will be more widely accepted, however.

The cropping system should be adapted to the soil and climatic conditions of the particular locality. Fertilization should provide sufficient nutrients, in addition to those furnished by sod crops, to balance the supply of available moisture. With the return of crop residues to the soil, this soil-management system would be expected to maintain an adequate level of organic matter and sustained production.

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The Grazing-Irrigated Region

Wynne Thorne

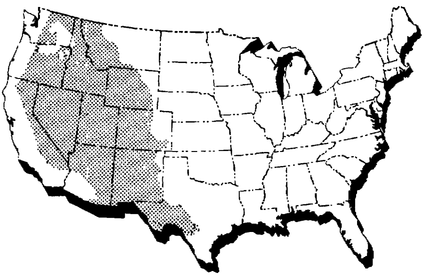
Mountains dominate the grazing-irrigated region of the West. The main spine of the Rockies divides the region somewhat east of center. The Sierra Nevada and the Coastal ranges on the west intercept moisture moving in from the Pacific; less rain falls east of them.

Precipitation is heavier near the western slope of the Rockies and reaches a maximum of 50 inches or more at the highest elevations. Rainfall again tapers off east of the Rockies, but not so much as in Nevada and western Utah.

Great variations sometimes occur within short distances. A small valley near the mountains may be covered with grass and trees, while less than 10 miles away the parched earth and scanty desert shrub vegetation give evidence of a drastically reduced rainfall. Many valleys in the mountains have occasional frosts in every month.

The mountains are less pronounced in Arizona and New Mexico. Desert conditions prevail generally. Rainfall is inadequate for crop production. Summer temperatures are high. Winters are mild. Some farming areas average 250 frost-free days a year.

A Great Plains type of climate prevails east of the Rocky Mountains. Temperatures often change quickly. Fluctuations in precipitation and temperature are greater than in the intermountain area.



The grazing-irrigated region is a land of extremes. People who are accustomed to the natural richness of the prairies and the humid forest lands may be appalled by the apparent aridity of much of this intermountain region when they see it the first time. They may agree with the report of Brigham Young's exploring parties that the only use of the land is to hold the rest of the earth together.

But close study of the agriculture of the region shows that there are essentially no wastelands. There are only different intensities of use. Productive irrigated pastures may graze a cow or more per acre—but in a desert shrub area 75 acres or more may be needed for one cow.

Irrigation is the key to an intensive agriculture in this area. Surplus moisture from the high elevations (principally above 7 thousand feet) is used on lands below. Ground waters are also pumped to supplement the water in streams and reservoirs.

The supply of irrigation water is adequate for only a small part of the land. Lands are chosen for irrigation according to suitability of topography for intensive agriculture, quality of the soil, and nearness to a water supply. Because less than 5 percent of the region is irrigated, the pattern of irrigated land appears on a map as only thin belts or isolated spots in the broad terrain of rangeland.

The intimate association of irrigated lands and rangelands favors livestock farming. The animals graze the range in appropriate seasons, and supplemental feed for them is grown under irrigation. Poultry and dairy industries are confined to irrigated regions and usually are concentrated near cities.

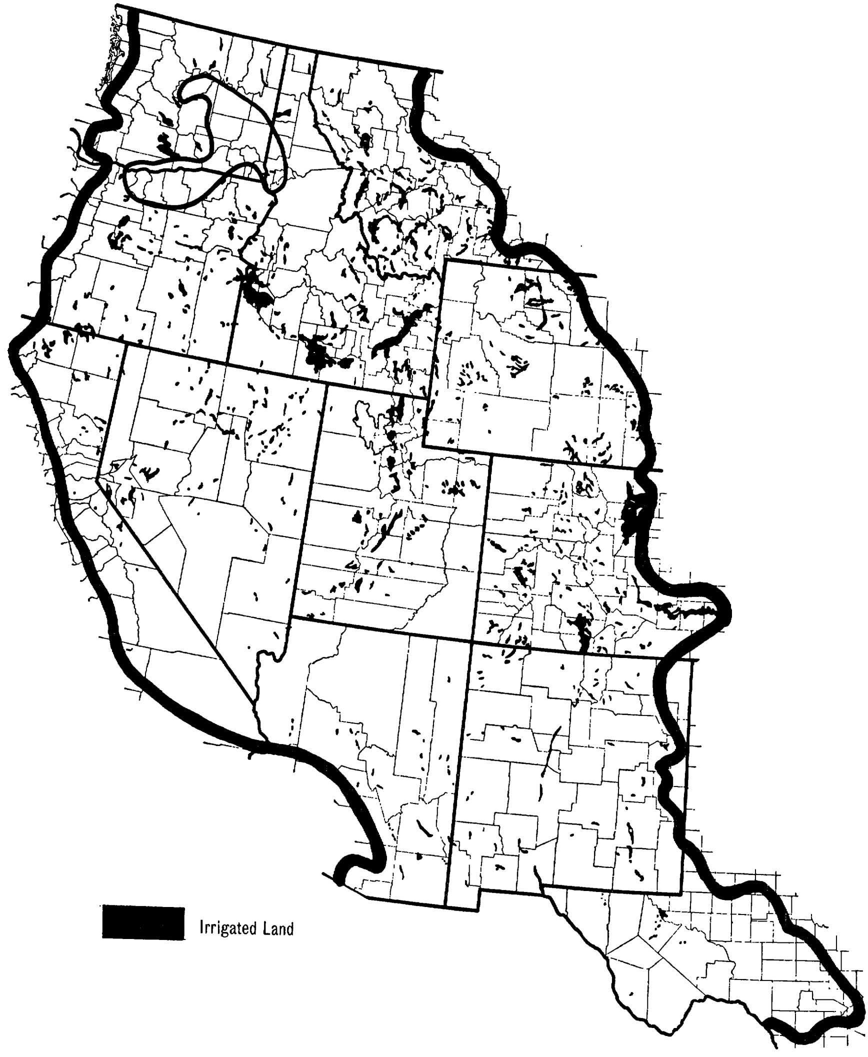
Income from livestock, other than from poultry and dairying, is more than 600 million dollars a year. The agricultural income from dairy products exceeds 100 million dollars and income from poultry is about 60 million dollars a year. Cash crops, another major source of income, bring more than 525 million dollars a year. Fruits, berries, and vegetable crops are major enterprises in some localities. Field crops, including sugar beets, potatoes, dry beans, small grains, corn, and sorghums, are grown extensively. Cotton is important in parts of Arizona, New Mexico, and Texas.

Noted for fruit production are the Yakima and Wenatchee areas of central Washington, parts of the Boise Valley of Idaho, the Flathead Lake region of Montana, the Wasatch Front region of Utah, the Virgin River Valleys of Utah and Nevada, the western slope of Colorado, and some of the irrigated valleys in eastern California.

General farming and cash crops are important in the Columbia Basin of Washington; the Lower Snake River area of Oregon and Idaho; the Upper Snake River Valleys of Idaho; Salt Lake, Utah, and Sevier Valleys of Utah; Yellowstone Valley, Big Horn Valley, and North Platte River areas of Wyoming; the eastern slope of Colorado, including the headwaters of the South Platte River; and the San Luis Valley at the headwaters of the Rio Grande. The lands along the Rio Grande and Pecos Rivers in New Mexico and Texas are irrigated and used for general farming, including cotton in the lower elevations.

Nonirrigated crops are important in scattered areas. Dry beans are grown in summer-rainfall areas of central New Mexico, southwestern Colorado, and southeastern Utah. Dryland wheat is important near the Palouse area, in south-central and southeastern Idaho, and in northern Utah. Alfalfa, barley, and wheatgrasses are also important.

Native vegetation and soil charac-



teristics are closely associated with climate. Short grasses are the dominant native vegetation east of the Rocky Mountains. Trees, grass, and shrubs appear in the mountains according to moisture, temperature, and soil conditions. Desert shrubs and the bunch grasses are dominant west and south of the Rockies. Sagebrush, rabbitbrush, greasewood, creosote bush, shadscale, and other shrub and browse plants predominate according to environmental conditions. Native plants remain on more than 90 percent of the land, and their character and density are major factors in determining the numbers of livestock that can be grazed.

Almost every major great soil group in the United States exists in this region. Soils typical of humid areas and forests occur principally in the high mountain areas and are not farmed, except in northern Idaho and Washington. The principal cultivated soils are those representative of arid zones.

Arid-region soils are generally low in organic matter and nitrogen; the amounts reflect somewhat the climate and native vegetation. Shrubs and bunch grasses are the principal vegetation in places where rainfall is less than 10 inches. The soils are light in color, alkaline in reaction, and often high in content of lime and mineral nutrients. Moisture is inadequate for farming except with irrigation. Such soils need organic matter for successful farming, and until it is supplied the soils run together and crust excessively.

As rainfall increases, native vegetation changes to sagebrush and larger shrubs and bunch grasses, then to short grasses. The content of organic matter in the soil increases accordingly and permits wider varieties of farming and farm crops. In most of the unforested parts, precipitation has been inadequate for leaching, and the soils therefore are generally alkaline in reaction and rich in mineral nutrients. Zones of lime accumulation are typical. They are near the surface in the deserts and progressively deeper in the higher rainfall belts.

Soils of all climatic and vegetative zones are used for grazing. Dryland farming is restricted to areas with 10 inches or more of precipitation. Irrigation agriculture occurs throughout the region wherever combinations of water, suitable topography, and good soils are available. Nitrogen deficiencies are general. Phosphate deficiencies are frequent. Iron deficiency, or lime-induced chlorosis, is common with susceptible plants. Zinc, manganese, and boron deficiencies occur in restricted areas and especially with fruit crops.

Soil erosion is a problem in all arid regions. Wind erosion occurs particularly in freshly cultivated Desert and Brown soils. Water erosion increases with rainfall. The limited rain in desert sections may come in downpours.

SALINE AND ALKALI soils are widely distributed throughout the region. Although the total acreage is large, these salt-affected soils are so closely associated with other soils that only limited, distinctive management practices are used for them.

Under range conditions, these soils have a naturally adapted vegetation. Where the salt or alkali situation is severe, usually no attempt is made to change the vegetation, although overgrazing may drive out many desirable forage plants.

Under irrigated conditions, the first attempt is toward reclaiming these soils, usually by installing drains and leaching to remove salts. Alkali often requires an additional treatment with such amendments as gypsum or sulfur. Often reclamation is economically infeasible, or poor-quality water perpetuates the problem. Then salt- and alkali-tolerant plants are selected, and management practices to reduce salt accumulation in the crop root zone are adopted.

Soils that have developed under forests occur in the northern part of the region and in scattered locations in the mountains. The rainfall is generally more than 20 inches where these soils exist. Cultivation of these soils is confined principally to the northern zone. Some of the soils are acid and need lime treatment for alfalfa and other acid-sensitive crops. Drainage is often needed. Nutrient deficiencies commonly encountered include nitrogen, phosphorus, potassium, boron, and sulfur. A wide variety of crops is grown, and although rainfall may reach 50 inches, summer droughts are common. Supplemental irrigation is practiced close to natural water sources.

It would seem that the grazing-irrigated region could be divided easily into subregions with similar agricultural practices and products. But the dominating influence of mountains scatters areas of similar soil and climate. We can speak of types of farming and cropping systems, but the areas involved may be distributed from Washington to New Mexico. For convenience, then, soil-management practices are here discussed according to types of farming that occur.

DRYLAND FARMING is crop production without irrigation where annual precipitation is less than 20 inches. Areas of dryland farming occur in all States of the region, but notably in Washington, Oregon, Idaho, Montana, and Utah.

Winter wheat is the principal crop grown without irrigation where precipitation is less than 15 inches. Spring wheat is grown in limited areas in the region and in most areas in years of severe winter killing. Dry beans are grown in central New Mexico, southwestern Colorado, and southeastern Utah where there is a pattern of summer rainfall.

The yields of all dryland crops are broadly dependent on precipitation, but soil-management practices also influence available moisture, soil erosion, and nutrient supply.

The variety of possible crops increases as the moisture supply exceeds 15 inches a year. Alfalfa for seed is grown in the more favorable soils and moisture sites. Barley production has increased, primarily because of Federal limitations on wheat. Some grass seed is grown, particularly crested wheatgrass in the lower moisture areas, and intermediate, stiff hair, and tall wheatgrass as moisture exceeds 12 inches.

The fallow system of farming is recorded in the Bible. Modern power machinery has advanced it to almost an art. Each year the land in fallow in this region exceeds 2 million acres. The practice of alternating wheat and fallow assumes that by clean cultivation much of the moisture coming during the fallow period is stored for use during the crop year. Available soil nitrogen increases and weeds are controlled during fallow.

Fallow leaves the soil exposed and susceptible to erosion by wind and water. Many fallowed soils crust or develop compacted zones, which take in water so slowly that runoff and erosion are excessive.

New types and procedures of tillage aid in control of erosion and improve water intake. The moldboard and disk plows are being replaced with chisels, sweeps, and other implements, which open and loosen the soil while leaving most of the straw on the surface.

This stubble mulch or trashy fallow system works well in areas of limited rainfall where the amount of straw produced does not interfere with tillage. Tillage implements have been adapted to cover some of the straw when there is too much of it.

Tillage on the contour helps prevent runoff on the steeper slopes. Some broad-base terraces have been used in the region, but the practice is not popular. Steeper slopes and waterways are planted to permanent cover.

Tillage operations may cause compacted zones at a depth of 5 to 8 inches, or just below the usual plow depths. The zones can be controlled by growing alfalfa at moderate intervals. The most usual control measure, though, is fall tillage of stubble land with chisels or sweeps set to a depth just below the compacted zone. The effectiveness of this deeper tillage on compacted soils is evident in reduced runoff and deeper penetration of moisture.

Timing of operations is an important byproduct of power machinery. The soil can be broken in the fall or early spring before weeds or volunteer grain deplete moisture. Fallow operations with a rod weeder or other equipment can keep weeds under control, and planting can be timed in the short period in fall or spring when temperature and moisture are favorable.

Applications of nitrogen fertilizer have zoomed upward on dryland wheat since 1945. Recommended applications for wheat after fallow in Washington are 20 pounds of nitrogen in places that have less than 13 inches of rain, 30 pounds of nitrogen with 13–17 inches of rain, and 50 to 60 pounds of nitrogen for annual cropping in the higher rainfall belts. Recommendations are similar in Oregon and northern Idaho.

A standard treatment of 30 to 40 pounds of nitrogen is recommended in southern Idaho and northern Utah for areas of good soil that get 13 inches or more of precipitation. Sections that have an average annual precipitation of less than 12 inches do not respond consistently to nitrogen, and treatments are suggested only for years when the moisture outlook is favorable.

Fall and spring applications have given somewhat equal results if the spring treatments are made before very much growth occurs.

The Washington Agricultural Experiment Station recommends band placement under stubble mulch, but results in Idaho and Utah have not shown any consistent difference between banding and broadcast applications.

No consistent differences have been found among various nitrogen fertilizers when applied in the same manner and at equivalent rates of elemental nitrogen. When it is applied in the fall, nitrate nitrogen tends to leach deeper than ammonia. Somewhat better increases in yields have been obtained in Utah from broadcast spring applications of nitrate carriers than from ammonia carriers. This has been attributed to quicker movement of the nitrate into the soil under these conditions of limited rainfall. In places where leaching is a problem, ammonia-type fertilizers are recommended for fall treatments, and application is delayed until soil temperatures fall to about 50° F.

The various wheatgrasses and mixtures of wheatgrasses and alfalfa are planted on abandoned and retired dryland wheat areas and on steeper slopes for forage and for soil protection. A firm, clean seedbed is recommended. Planting the grasses in early fall or early spring in northern areas and late fall in southern areas is suggested. Alfalfa should be planted in early spring or during periods of heavy rainfall. Complete protection from grazing is usually needed for 2 years.

Alfalfa grown for seed on drylands should be planted in rows, usually 24 to 36 inches apart. Cultivation between the rows is practiced the first year to control weeds. Planting for seed production is not usually recommended when precipitation is less than 15 inches.

Alfalfa is grown for forage in some of the more favorable sites. Alfalfa improves the structure and the content of organic matter and nitrogen of the soils. A minimum of 5 years in alfalfa is required to impart maximum benefits to the soil.

Legumes in rotation tend to increase wheat yields in areas that have 16–18 inches or more of rain. At lower moisture levels, moisture depletion by the legumes offsets the benefits from nitrogen and organic matter residues. Peas and clover failed to benefit wheat yields when planted in alternate years on a deep loam soil from 1916 to 1952 at the Nephi Dryland Experiment Farm in central Utah, where the average rainfall is 12 inches. After the termination of the experiment and with wheat alternating with fallow, however, the residual benefit from the legumes was reflected in increases of 5 and 6 bushels of wheat the acre.

General irrigated farms of the region include a variety of enterprises. Some livestock and cash crops usually are included, but the major source of income is not any single enterprise. These farms are widely scattered. There are many of them in the Columbia Basin of Washington and Oregon; along the Snake River; in the Great Basin; along the Rio Grande, Pecos, and Arkansas Rivers, and at the eastern front of the Rockies in Colorado and Wyoming.

The irrigation water comes primarily from rivers or mountain streams. Some water is pumped from underground supplies. Most of the water is of good quality. Low-quality water is encountered oftenest where drainage water and other return flows to stream beds are used a second or third time for irrigation.

General irrigated farms occur on a wide variety of soils and in a range of climates, but mostly they are below elevations of 5 thousand feet, where the growing season is long enough.

Many problems affecting soil man agement occur—small size of farms, poor rotations, salt and alkali in soils, poor drainage, irregular topography, inadequate supplies of irrigation water, weeds, low fertility, and erosion.

Several significant trends in improvement of general irrigated farms have taken place since 1945. Financial assistance from the Federal Government has helped improve land and distribution systems for irrigation water. The technical assistance for these programs is centered with the Soil Conservation Service, but it is also carried out by other Federal and State agencies. The technical assistance to farmers consists of making farm plans with changes in field layouts, irrigation systems, cropping systems, fertility practices, and general farm improvement and making the necessary surveys and plans.

Land leveling has become the most popular and extensive of these farm improvement programs. More than half the money paid for assistance to farmers by the Agricultural Stabilization and Conservation Committee in Utah in 1955 was for land leveling. With agronomic and engineering assistance, land is surveyed and the surface is reshaped to uniform slopes through the use of heavy power equipment, including carryalls and landplanes. The leveling reduces labor of irrigation and makes possible a more uniform distribution of water.

Leveled land must be handled with care. Poor plowing, failure to use a farm level, and erosion or deposition of soil by careless irrigation may destroy a leveling job in a few years.

Irrigation distribution systems have been improved. Often open ditches are replaced with underground pipe with risers at appropriate locations. Farm ditches are being stabilized to reduce erosion and increase the efficiency of irrigation.

Overnight storage reservoirs make possible a better job of irrigation, and are helpful also when the irrigation stream is too small for effective use. The reservoirs, which commonly hold 2 to 20 acre-feet of water, are at a high elevation near the cropland to permit use of the water on as much of a farm as possible.

Another important trend has been toward larger farm units. Modern machinery and farm practices have greatly increased the amount of land one man can operate, but only with increased employment opportunities since 1945 has there been a reduction in number of small farms. The large number of small farms is still a deterrent to many desirable practices, including crop rotations that improve soil and adequate measures to control weeds.

Crop rotations are less standardized on general irrigated farms than on most other farms. Because much of the income is from cash crops, there is a tendency to watch markets carefully and to plant crops that hold promise of largest income. Labor supply, the yearly outlook for water, and many less tangible factors also lead to major shifts in cropping.

Although there is an aspect of opportunism in crop selection, a basic element of crop rotation is usually followed. Alfalfa is the heart of the rotation on most general irrigated farms of the region. It serves the multiple purposes of being the major feed for livestock, aiding in weed control, building up organic matter and nitrogen in soil, improving the physical properties of soil, and aiding in controlling soil-borne insects and diseases.

Alfalfa is often planted with a nurse crop such as a small grain or peas, which are seeded at about half the usual rate. The successful use of nurse crops requires that irrigation practices favor the alfalfa rather than the nurse crop and that irrigation be continued after the nurse crop is harvested. Alfalfa is cut for hay 2 years or more, depending on the need for hay and prospects for cash crops.

Alfalfa is followed in rotations by a variety of crops, preferably crops that can take advantage of the nitrogen left by alfalfa and that can be managed without interference from alfalfa root residues. Potatoes and field corn or sweet corn are grown extensively following alfalfa. Other commonly used crops are beans, sorghums, cotton, and sugar beets.

Various crops are planted the second year following alfalfa—almost any of the vegetable crops, sugar beets, and the small grains. Land often is kept in row crops more than 2 years following alfalfa. In such long rotations, the row crops not immediately following a legume should be fertilized liberally. Usually a close-grown crop, such as peas or a small grain or clover, is alternated with row crops.

Fertilizer practices differ greatly. Phosphate usually is applied to land planted to alfalfa and such cash crops as sugar beets, cotton, potatoes, and vegetables. Corn and small grains seldom respond to phosphate treatments on well-managed irrigated farms.

Nitrogen fertilizers are commonly reserved for row crops planted the second year or later after alfalfa. Corn and sugar beets, however, usually need more nitrogen than is supplied through the rotation or farm manure.

Recommended fertilizer treatments include 80 to 120 pounds of available phosphate as superphosphate an acre at the time of planting alfalfa or clovers. Sugar beets should receive 40 to 120 pounds of nitrogen an acre (according to soil fertility), and phosphate and potash fertilizer as need is indicated by soil tests.

In Idaho, 80 pounds of nitrogen and 40 pounds of available phosphate are recommended for potatoes following a row crop, with 20 pounds less nitrogen following alfalfa.

Corn needs liberal treatments with nitrogen and irrigation water. Applications of 80 to 160 pounds of nitrogen an acre are recommended. Experiments in Arizona indicate that 100 pounds of nitrogen and 50 pounds of available phosphate are desirable for irrigated cotton.

Rotation pastures need highly fertile soils. A common fertility treatment is 80 to 120 pounds of available phosphate every third year and 10 to 15 tons of manure every second year. Irrigation is needed to meet the needs of drought-sensitive plants in the mix such as Ladino clover.

The moldboard plow is usually recommended for irrigation farms. Heavier textured soils should be fall plowed. Spring operations include a minimum of once over with a farm level and harrowing.

Alfalfa, small grains, and other close-planted crops are irrigated between borders by flooding from ditches. Row crops generally are irrigated by furrows. Subirrigation is practiced in limited areas where soil conditions permit. Sprinkler irrigation has been increasing rapidly, particularly in places where topography is unfavorable for surface applications.

All crops should be adequately supplied with water throughout the growing season. No advantage is gained from allowing crops to wilt or show distress from lack of water. Frequently such distress significantly reduces yields.

Dairy farms numbered more than 17 thousand in this region in 1950. Almost half of them were in southern Idaho and central and northern Utah. Nearly all dairy farms are irrigated.

Their size varies, but in 1957 at least 20 cows were needed for a successful full-time operation. Assuming a minimum of 2.5 acres for each cow and her calves on the higher producing farms, a minimum size for a dairy-farm unit which produces most of its own feed would be about 50 acres. Usually dairy farms are much larger, and often more than 2.5 acres are required for a cow.

Each cow with calves might be expected to require about 0.4 acre for grain, 1.2 acres for hay, 1 acre for pasture, and 0.4 acre for silage. This might serve as a rough guide to rotations for a dairy farm. In most instances, however, a dairy farm produces some cash crops, and frequently part of the feed is purchased.

A dairy farm growing sugar beets

as a cash crop (which will also furnish beet tops and beet pulp for feed) would possibly be divided into 10 fields. A rotation of barley (nurse crop for alfalfa), alfalfa, alfalfa, alfalfa, alfalfa, corn (for silage), and sugar beets would occupy 7 fields. A rotation pasture would occupy three fields. Every 2 or 3 years a field would be plowed from pasture. The year preceding this, a field most recently used for sugar beets would be planted to pasture with a barley nurse crop. In order to make up for the overlapping, one year could be cut from alfalfa each year a pasture is planted.

This represents only one type of rotation adapted to a dairy farm in this area. Milo might be substituted for corn and cotton for sugar beets in the Southwest. Potatoes, tomatoes, beans, sweet corn, or some other crop could be used in place of sugar beets in other areas. The second row crop could be omitted on farms where dairying is the only interest, and the required number of fields could be reduced proportionately. The dairy enterprise does permit a standardized rotation with freedom for changes in the cash crop.

Dairy farms frequently have permanent pastures in poorly drained fields or on soils not suited to other crops. Such pastures are seldom adequate for high-producing cows but can be used for calves and dry stock.

In view of the need for a regular rotation of pastures and crops in sequence, a dairy farm should be carefully selected and planned. The soil should be deep and well drained. A finer textured soil can be used successfully here, though, than can be used on most general irrigated farms. The topography should be uniform and nearly flat to gently sloping. There should be an irrigation stream of two or more cubic feet per second so that pastures can be irrigated rapidly and uniformly. Many undesirable variations from this ideal occur, and allowance must be made for them in management practices.

A dairy enterprise usually creates a favorable soil fertility situation. Alfalfa and rotation pastures add organic matter and nitrogen to the soil. The manure from the animals furnishes added nutrients and is usually distributed on pastures and on land to be planted to row crops.

Phosphate is the principal commercial fertilizer used on dairy farms in most of this region. It is usually added to soil preceding the planting of alfalfa and pasture. If, as in the example, pasture is left in 6 years or more, supplemental phosphate is usually broadcast on the surface of the pastures every second or third year.

The phosphate added should provide 30 to 50 pounds of available phosphoric acid per acre per year, depending somewhat on the length of growing season and soil conditions. Farm manure treatments provide about 5 pounds of phosphate per ton and so may furnish an important part of the total needed throughout a rotation cycle.

Other plant nutrients may be needed under restricted conditions. Potash is usually needed in the northern cutover timberlands of Idaho, Washington, and Montana. Sulfur, boron, and lime often are needed in that area. Potassium may also be needed in spots throughout the entire region, but field tests by the various State agricultural experiment stations have shown only infrequently any response to potash fertilizers in other than forest soil areas. Some nitrogen fertilizers may be needed on row crops.

Livestock ranches involve the closest integration of the varied agricultural aspects of the region. Sheep or cattle graze the rangelands that lack water or are unsuited for crop production. Cropland is usually associated with these range operations to produce hay and other feeds to supplement the range feed. The amount of crops fed varies greatly with location and type of ranch.

Usually the sheep ranch has a summer and winter range, and supplemental feeding occurs principally during the lambing period and during exceptional winter weather when snow is too deep for range feeding.

The cattle ranch commonly involves more supplemental feeding than the sheep ranch. Often only a summer range is available for cattle in the northern half of the region. In practically the entire region the finishing of beef animals for the market must be done by dry-lot feeding, although many grass-fattened animals are sold for the market or for feeders.

High, short-season valleys in the mountain area are adapted principally to livestock production. The short season and occasional frosts almost every month during the summer limit the kinds of crops and the yields obtained. Agriculture is on an extensive, rather than an intensive, scale. Pasturelands usually are considered permanent pasture, and the cropland is planted to hay and grain. Often the principal hay crop is grass meadow, which is cut in August for hay and grazed during the fall. Alfalfa, when it is grown, is left in as long as possible. Small grains (usually barley) are grown only for a year or two while the land is being prepared to go back into alfalfa.

The alfalfa-small grain system presents no special soil-management problems not already discussed. In many instances, however, the climate, soil, and water would permit greater feed production if corn or sorghum followed the plowing out of alfalfa. Also, the alfalfa too often is inadequately fertilized or left in after the stands have become thin.

Many of the permanent pastures are on poorly drained land or land flooded for excessive periods. Such pastures in the higher altitudes are known as mountain meadows.

Mountain meadows occur in many mountain valleys where early spring runoff and streams of water are diverted over meadowland and allowed to run over the land almost continuously until the size of stream is inadequate to cover the area or until the meadow approaches the harvest stage. Several million acres of such mountain meadowlands exist in the region.

The length and depth of continuous flooding determine the types of vegetation present. If flooding is for only 2 or 3 weeks during early spring runoff, many common grasses and legumes, such as bluegrass and whiteclover, are present. Areas flooded for long periods with shallow depths of water, usually less than 6 inches, develop mixtures of rushes, sedges, and grass. Many of these species are low in digestible nutrients and protein. When floods last long at depths greater than 6 inches, rushes and wiregrass tend to predominate, and the feed value is low.

Intermittent irrigation instead of continuous flooding does not increase the yield or quality of forage unless plant species are also changed.

Fertilizers applied to the mountain meadows increase yields, but often the increases are not profitable. The largest responses have been to nitrogen fertilizers. Phosphate fertilizers have not been beneficial except in places where clovers were present.

Extensive experiments in Colorado since 1950 have indicated that best results are had by a complete change in management, including plowing up the native sod, reseeding with improved mixtures, fertilizing, shifting to intermittent irrigation, and cutting at earlier stages of plant development. The rewards from these changes included higher yields and greater feed value of the hay produced.

In terms of pounds of beef produced per acre, continuously irrigated, unfertilized, late-cut hay near Gunnison, Colo., in 1951 produced 200 pounds. Fertilized, intermittently irrigated, early-cut, reseeded meadows produced about 800 pounds.

How to eradicate native sods is probably the biggest problem in reseeding old meadows. The sod is so tough that special equipment and a year or more are needed to break it down to a suitable seedbed.

Reseeding mixtures are varied according to soil, moisture, and climatic conditions. Grass species commonly used are mountain brome, smooth brome, orchard, tall fescue, and reed canary. Legumes include Ladino clover, whiteclover, alfalfa, alsike clover, and strawberry clover.

Much of the rangeland is federally owned and managed by Federal agencies, such as the Bureau of Land Management and the Forest Service. Privately owned range commonly represents better sites than does the public domain.

The most widely adopted practices for soil conservation and range improvement are grazing control, with a general trend to reduced numbers of livestock and better timing of grazing to protect desirable plants; developing sources of drinking water to promote more uniform grazing of the entire range; trucking sheep between ranges, rather than trailing them; and range reseeding.

Eradicating old brush stands, preparing a favorable seedbed, controlling depth of planting, timing planting operations, and protecting new seedlings until established are essential steps in range reseeding. Crested wheatgrass is the most extensively planted grass for reseeding ranges. It is also one of the most drought tolerant. Other grasses include intermediate, pubescent, and tall wheatgrasses, Russian wildrye, and Indian ricegrass. Common rye often is planted on favorable sites for temporary spring or fall grazing.

FRUIT is produced throughout the region, but commercial production is limited to a few somewhat isolated but important locations. Large volumes of apples, peaches, pears, apricots, and cherries are produced. Berries are grown extensively.

Essentially all fruit is produced under irrigation, which means water-holding capacity of the soil is less critical than in humid, nonirrigated regions. Orchard soils must be deep, permeable, well drained, and free of excess salt and alkali. Loam soils are most desirable, but orchard production is successful on sandy and gravelly soils and on many clay soils that are granulated and permeable.

Variations in rootstalks modify soil adaptations, but in general pears, plums, and apples seem adapted to soils of finer texture than peaches, cherries, or apricots. Grapes root deeply and have requirements similar to fruit trees. Berry crops are adapted to most areas where tree fruits grow.

Chlorosis is a problem in irrigated areas, and sites conducive to it should be avoided. No completely reliable criteria for identifying chlorotic areas are now available. In general, however, soils high in lime and particularly those which have a marly accumulation within 3 feet of the surface, combined with a fine texture and compact structure, should not be used for extensive fruit plantings unless preliminary trials indicate that chlorosis is not a problem.

Most fruit and berry crops are highly sensitive to salt and should not be planted on the saline or alkali soils. Peaches, apricots, and cherries seem especially sensitive to chlorides. After grapes have been established, they seem to tolerate moderate quantities of salt. Irrigation water should be low in salt and sodium.

The biggest limiting factor in commercial fruit production is climate. Air drainage is important. Good air drainage is favored by moderate, continuous slopes more than by short, steep ones. Air drainage inverts the usual altitude relations in which there is an average decrease of about 1° F. for every 300 feet of increase in altitude.

Other climatic factors, such as wind and hailstorms, may vary considerably between different sites in the same locality. Sites near the mouths of canyons may have sufficient wind to damage fruit. Windbreaks are helpful in those areas, but they should not be too close to the trees lest frost damage be increased on the leaward side.

The trend is toward planting fruit crops on land too steep for most other tilled crops. Orchards or vineyards to be planted on steep slopes and irrigated in furrows must be laid out with the rows on contour grades generally not exceeding 2 percent. This requires careful planning and often some preliminary smoothing of the soil surface to avoid extreme fluctuations in row width. Because of these difficulties and the problem of wetting any large proportion of the soil surface from furrows, sprinkler irrigation is being adopted for most areas of steep slopes.

Clean cultivation was formerly the common orchard practice. Recommendations now are for green manure crops or controlled weed growth to protect the soil and to build up the organic matter.

Tillage operations in orchards should be reduced to a minimum necessary to prepare land for irrigation and to plant and control cover crops and weeds at strategic intervals. Implements that penetrate the soil more than 4 or 5 inches may greatly injure tree roots.

Oil sprays to control interplanted vegetation in orchards have become common. They largely eliminate soil cultivation, especially in orchards irrigated by sprinkling. Oil sprays kill the vegetation and leave it as a mulch on the soil surface; the mulch aids soil granulation and encourages feeder roots near the soil surface. Reduced tillage may reduce soil compaction.

To wet the soil as uniformly as possible, irrigation furrows in orchards should be broad, shallow, and spaced at about 3-foot intervals between the tree rows. Border and basin systems often are used where the land is nearly level or has a uniform slope. Overhead sprinkling is used widely, and the practice is increasing. Special nozzles that throw the water out below the branches are used.

While trees draw water from soil depths of 5 feet or more, most feeder roots are in the upper 2 feet, and this zone should not be permitted to dry out between irrigations.

Organic matter is maintained in orchards through applications of farm manure and green manure. Rye, vetch, and sweetclover have been used extensively. Objections to sweetclover are its excessive growth and the fact that its demand for plant nutrients and soil moisture coincides with the peak demands of trees. Winter vetch and Austrian winter peas avoid competition with trees and give a good supply of organic matter by late spring or summer.

Alfalfa is used extensively for soil cover in apple and pear orchards. For peaches, apricots, and cherries grown on moderately coarse-textured soils, alfalfa furnishes undesirable competition for water and nutrients. Unless it is properly managed, alfalfa may encourage harmful insects, such as the tree leafhopper. Alfalfa is particularly helpful in orchards where chlorosis is a problem. Where alfalfa is grown, the top growth should be left in the orchard and worked into the soil, rather than harvested for hay.

Rye, mustard, and other nonlegumes need supplemental nitrogen for growth and decomposition. In central Washington, 200 pounds of ammonium sulfate an acre is recommended just before rye is planted.

For berries and grapes, it is usually not feasible to grow interplanted crops to maintain or build up organic supply. For these crops, soil organic matter should be built to a maximum before plantings are made. Supplemental additions can be made during the growth period as manure or mulches.

Irrigated fruit crops in the region have shown deficiencies of many elements. Nitrogen deficiencies are general. Phosphate deficiencies are not common, but some phosphate is widely used as an aid to cover and green manure crops between trees. Potassium is usually adequate although some growers believe potash improves quality.

Other elements frequently deficient are iron, zinc, manganese, and boron.

Nitrogen deficiencies are typified by light-green color in leaves and reduced growth and vigor of plants. There is no one rule to determine application rates of nitrogen fertilizers. A common plan is to add sufficient nitrogen to give the desired average length of annual terminal growth. A 12-inch growth is considered desirable for bearing peach trees in Washington. Optimum annual growths for many apple varieties have been suggested in some areas. A second plan is to add as much nitrogen as possible without seriously reducing fruit color or quality.

The preferred time for nitrogen applications varies with areas and types of fruit. Early spring or fall applications are generally favored for deciduous fruits. Late-summer treatments delay ripening and may increase frost damage by encouraging late growth. Actual annual treatments are 60 to 120 pounds of fertilizer nitrogen an acre. Most mixed fertilizers for established fruits contain about twice as much nitrogen as phosphate.

VEGETABLE CROPS are grown throughout the region, but extensive commercial production is limited to population centers and areas with moderate to long growing seasons. Vegetable crops generally are expensive to produce and market.

Deep, well-drained, sandy soils are preferred for winter and early planted vegetable crops. Medium-textured soils, mucks, and even light clays often are used for warm-season crops. Soils that are difficult to cultivate should be avoided because land planted to vegetable crops must be frequently worked.

A few vegetable crops, such as table beets, kale, and asparagus, produce well in rather saline soils. In general, though, saline soils are not adapted to large yields of high-quality produce.

Topography also is a major consideration. Many vegetables need careful control of soil moisture. Labor costs for irrigation often are high. The land should be nearly level or of a moderate, even grade to permit uniform wetting.

Many vegetables have small seeds and need a clean, firm, moist seedbed. Good, uniform stands must be obtained to maintain essential quality and yield. Crooked, uneven rows and rough land interfere with cultivation.

In areas with severe winters, clay loams and clay soils should be fall plowed if early vegetables are to be planted in the spring. The yield and quality of peas, lettuce, and other crops are greatly reduced when planted so late that growth must extend into hot weather.

Vegetable crops differ appreciably in rooting depth and irrigation requirements. Because different crops have different irrigation requirements, water should be available on demand.

Many vegetable crops remove large amounts of plant nutrients from the soil, so that liberal fertilization is necessary. Farm manure is customarily applied to vegetables if it is available. The most usual ratio of fertilizer for vegetables in this region is 1–1–0 or 2–1–0. Potassium is added more often to vegetable soils than for other crops. Tomatoes often crowd the growing season, and nitrogen is used conservatively to limit prolonged vegetative growth and delayed ripening of the fruit. The most usual fertilizer for tomatoes has a 1–2–0 ratio; if they are planted following alfalfa, no nitrogen is used.

SOIL-MANAGEMENT RESEARCH in the grazing-irrigated region since 1945 has emphasized the advantages of combining desirable practices. Improper tillage operations that cause soil compaction may nullify improved fertilizer and irrigation practices.

H. B. Peterson and J. C. Ballard reported studies with combinations of irrigation water and nitrogen fertilizer needed for maximum yields of sweet corn in northern Utah.

Without nitrogen fertilizer, there was little response to increased frequency of irrigation. With nitrogen fertilizer, but with no change in irrigation, yields increased only moderately. But when the nitrogen fertilizer treatment was increased to 200 pounds of elemental nitrogen to the acre and a continuous supply of moisture was maintained in the root zone, the yield increased nearly 300 percent.