Colorado's Agriculture and Forestry

Prepared by Colorado State University
Fort Collins, Colorado
for
Colorado State Department of Natural Resources
July 1957

AN INTEGRATED POLICY FOR THE CONSERVATION AND DEVELOPMENT OF THE NATURAL RESOURCES OF COLORADO

PRELIMINARY REPORT

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Technical Paper No. 1. "A Critical Survey of Several Forecasts of the Population of Colorado," by William Petersen, Associate Professor of Sociology, University of Colorado.

Technical Paper No. 2. "Nature of an Industrial Complex Based on the Development of Oil Shale on the Western Slope of Colorado," by Walter Isard, Professor of Economics, University of Pennsylvania.

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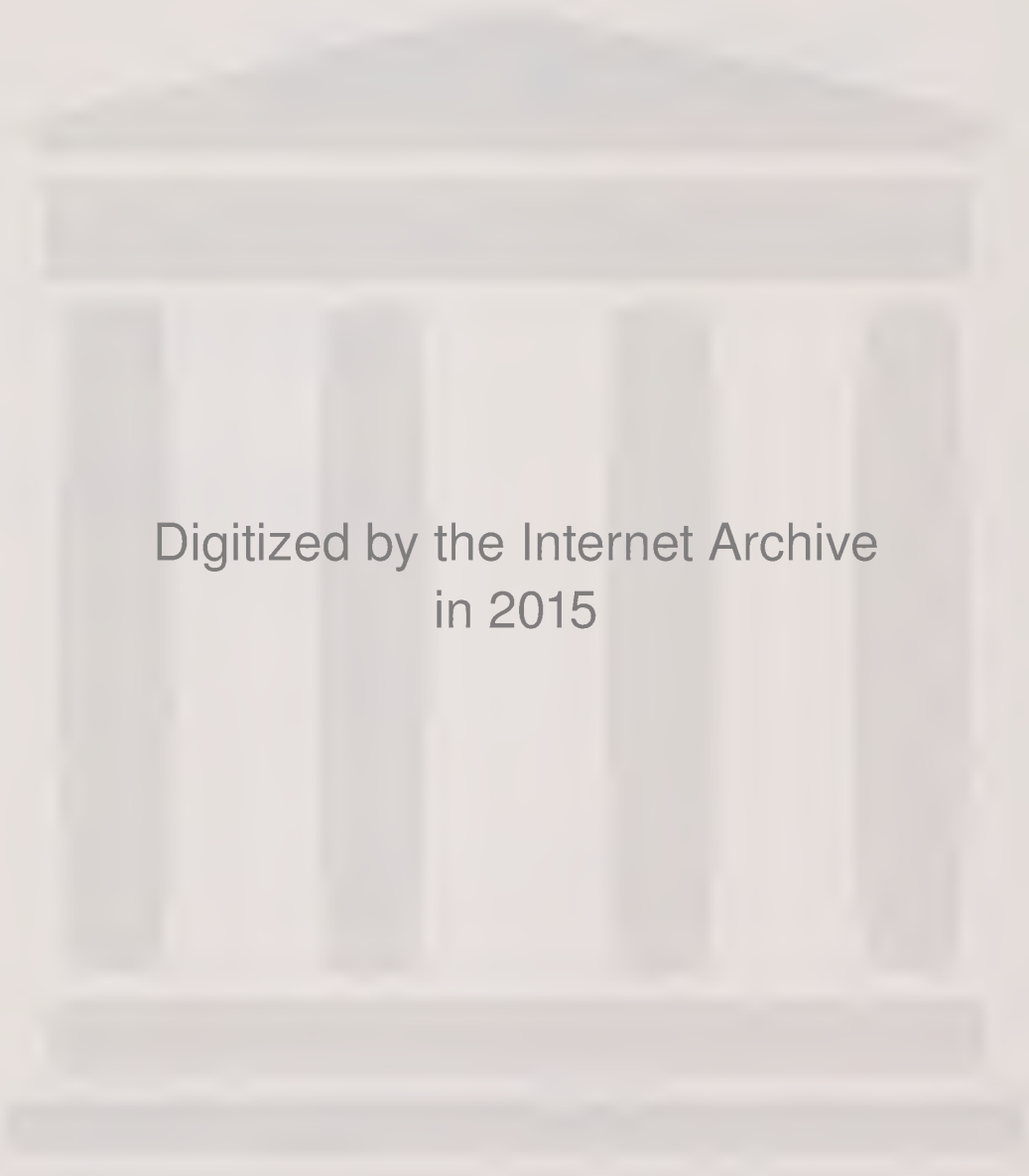

UNIVERSITY OF COLORADO

BOULDER, COLORADO

Hon. Stephen L. R. McNichols
Governor of Colorado
State Capitol
Denver, Colorado

Dear Governor McNichols:

In accordance with your desire to provide for the integrated development and conservation of the natural resources of Colorado, and to supply the newly created Department of Natural Resources with a basis for policy formation, I have the honor to submit the attached report on Agriculture and Forestry.

This is the second of nine studies which are designed to give an overview of the interdependence of the state's resources and the interrelationships of its resource problems. The studies are listed on the inside cover.

The present report was prepared as a committee assignment at Colorado State University. Mr. S. Avery Bice acted as chairman and Mr. Lowell Watts as vice-chairman. Mr. A. J. Hamman, retired Extension Irrigation Specialist, worked as a professional assistant. Staff members of the Departments of Agronomy, Civil Engineering, Range Management, Forest Management and Utilization, and Economics, the University Extension Service, Experiment Station, and Information Service, contributed generously to the composition of this report.

Cooperation was extended by all State and Federal agencies from whom it was requested, including the Soil Conservation Service, the Forest Service, Agricultural Stabilization and Conservation, the Weather Bureau, the Bureau of Reclamation, the State Department of Agriculture, the State Soil Conservation Board, the Colorado Water Conservation Board, State Board of Land Commissioners, State Planning Commission, and the State Forest Service.

Sincerely yours,

Morris E. Garnsey
Consultant on Natural Resources

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EDITOR'S PREFACE

This study is the first attempt to survey the whole range of Colorado's resources for agriculture and forestry in order to see what the resources are and what are the basic problems in using them. From this survey, it is hoped groundwork can be laid for action by the state and its citizens to bring about orderly development of land and forest resources and to use them wisely in the interest of the future.

No other study in this series will make more abundantly clear the interdependence of all the state's natural resources and the need to take all resources into consideration in making plans to develop any one of them. Agriculture, for example, depends heavily on an adequate supply of water. It is essential therefore to make the best possible use of water already available and also to develop new sources of both surface and underground water. Moreover, the claims of industry, cities, mining, and recreation must all be considered and brought into balance. The study on water resources will discuss these problems in detail.

Mountain ranges are important not only for agriculture but also for water supply, for forestry, for recreation, and for mineral development. The use of mountain ranges will therefore be discussed in several studies in this series.

The importance of conservation, or wise use of resources, is another main theme of the present study. Citizens of Colorado who have experienced major dust storms in the past are fully conscious of the need for holding soil by avoiding overuse or misuse. The need for another kind of conservation is shown in the forestry section, which points out that selective cutting of timber is essential to healthy forest growth and maximum sustained yield. Good forestry practices, in turn, will conserve our limited supplies of water.

All sections of this study indicate the important role of the federal government in resource development in Colorado. Not only is it the owner and manager of a third of the land area, but its policies on leasing and on reclamation payments have important repercussions on land and water use. This does not, however, prevent the state from developing a sound long-range policy for its resources. Such a policy, once developed, should tend to make federal contributions more effective than they are today, if only because the State would be in a position to point out where federal policies conflict or in other ways fail to serve the public interest.

At several points in the following pages, it is indicated that future development of Colorado's resources depends in part on needed changes in state legislation and local governmental organization. The state has begun to work on its underground water law. Forestry laws are in great need of updating. The lives and property of citizens may depend on better legal and administrative provisions for fighting forest fires.

Finally, there is evident in every area of agriculture and forestry a great need for research in how to use and develop land and forests more intelligently. Coupled with this is the need for an accelerated program of public education and information. Expenditure of public funds for these purposes would be money well spent, for it would enable us to make better use of what we already know and what we know how to find out.

M.E.G.

SUMMARY OF RECOMMENDATIONS

Principal recommendations of this report are listed below:

Part II--Irrigated Agriculture

It is universally recognized that water availability is the most limiting factor to future development of any area. The unmistakable meaning of this situation is that competition for available supplies will increase; that present users must be able to justify their use of this resource. All of the following recommendations are conditioned by this truth.

Recommendations

(1) Vigorous effort should be undertaken immediately to resolve the east slope-west slope controversy over the use of Colorado water. Plans should be made now to use all unallocated water within the state before downstream states establish legal right, through use, to this water.

(2) The state should intensify cooperation and coordination with the water programs of the federal government and with local affected groups inasmuch as future water projects will require large expenditures which smaller government or civic entities may not be able to finance. Potentialities of the small Reclamation Projects Act should be fully explored.

(3) Research should be intensified to arrive at an accurate inventory as well as a better public understanding of the ground water resources and their limitations; as soon

as practical results of the ground water study are obtained, legislative follow-up will be mandatory to put this ground water to the most beneficial use.

(4) Immediate consultations should be undertaken with highway authorities in an effort to reduce needless economic damage to irrigated land resources by super highway right-of-way requirements.

(5) A broad study of the administration of irrigated water in the state should be made to (a) codify present water statutes, (b) to facilitate changes in diversion points, and flexibility of storage and beneficial exchange policies, and (c) to define beneficial use. Also a review of the entire water distribution system within the state should be made in an effort to reduce evaporation and seepage and other in-transit losses of water. A corollary purpose in studying the results of the aforementioned would look toward possibilities of consolidating some present systems to eliminate wasteful duplication.

(6) New and intensified research should be launched into such problems as irrigability of soils, reclamation of saline and alkaline soils, determination of chemical and physical properties of soils, etc. A long-range program should be instituted to determine the practicability of drainage for some 800,000 acres of Colorado land to restore its productivity.

(7) Acceleration of present soil-water-plant studies should be made to determine such information as the best time

to irrigate, residual effects of irrigation water, leaching losses, and related problems.

(8) The state should adopt a strong program in support of education of the farmer in efficient water use.

Part III--Dryland Agriculture

Much of Colorado's dryland agriculture is located in an area characterized by high-risk production conditions. This results in recurring periods of economic instability and a consequent tendency to misuse land resources. In relation to their effects on land-use, federal programs and policies are inconsistent. Lack of general agreement on what constitutes constructive long-range solutions presents a challenge not yet successfully met.

Recommendations

(1) An adequate research and educational program must be maintained to provide information needed for wise resource use decisions by farmers in the dryland areas and to aid the department of natural resources in recommending land-use policies. This program should include (a) summarizing of past, present and future climatic data; (b) promoting effective use of the limited moisture received through studies of the effect of plant food supply, increasing moisture on some lands at the expense of controlled runoff to adjacent lands, breeding more drouth-resistant crops, improving tillage and seeding methods, further improving cropping systems, investigating principles of evaporation and methods to reduce it, and broadening studies of fallowing methods; (c) seeking better methods of improving soil structure and reducing deterioration of soils, controlling soil blowing and water erosion; and combating insects and diseases.

(2) A system must be agreed upon for classifying all eastern Colorado dryland by the type of use that can be carried on from year to year, during good climatic conditions and bad, in the interests of the health, welfare and safety of the public. Careful study is requisite to establishment of need for added state legislation to compel land use adjustments or to regulate its use. Certainly, any such need will be greater in some locations than in others.

(3) Study is needed of ways and means of increasing the economic stability of both the individual and of governmental units.

Part IV--Plains Range Livestock Operations

Plains range livestock operations are found in the same geographic area as most of Colorado's dryland agriculture, and are, therefore, subject to the same climatic limitations. By reason of the extensive rather than intensive use of resources for livestock production, land use problems of public concern occur less frequently than in cropped areas. This, however, does not remove the problem of recurrent economic instability or the need for handling range resources in a manner to maximize reserves and flexibility.

Recommendations

(1) An intensive study should be undertaken at existing research areas to determine possibilities for accurate prediction of range forage production and range seeding success based on climatic and soil moisture data.

(2) An experimental range in the 11- to 13-inch precipitation belt of eastern Colorado should be established to study the best systems of range use, proper rate of stocking, and management practices.

(3) A full time range management specialist is needed to help plan and execute educational and publicity programs that will help to put better range management practices into practice.

(4) Personnel trained in range management should be on the staff responsible for administration of state lands.

(5) In order to provide incentive for proper rates of stocking rangelands, and for equitable tax assessment of range-

lands, studies should be made of the feasibility of establishing three to five grades of grazing lands, based on potential productivity.

(6) Study should be made to determine the feasibility of setting aside a portion of the revenue from state land leases to be used for protection and improvement of the state's rangelands.

(7) Authorities concerned with highway building should be required to make effective right-of-way seeding programs a definite part of construction programming.

(8) Research and action programs should be accelerated on methods and economics for control of noxious and poisonous plants and various range rodents.

Part V--Mountain Range Livestock Ranching

Mountain range resource use is inescapably conditioned by federal ownership and use policies for forest and rangelands. But wise use can be strongly influenced by adopting the listed recommendations.

Recommendations

(1) Need is apparent for a range sheep experiment station similar to the Eastern Colorado Range Station.

(2) Studies for control of weedy trees, shrubs and herbs which have little grazing value should be continued. Meanwhile, future studies should look into possible industrial uses of the oils, resins, fibers, and other commercial products which may be derived from these presently useless plants.

(3) Range improvement studies should include (a) expanded research on the management of Ponderosa pine bunch-grass ranges on the front range and the mountain grass and aspen range on the west slope; (b) a study of improved methods of managing game habitats; (c) development of a basis for balancing livestock grazing, game grazing, water production, and timber production; (d) a study to appraise and control range rodents; (e) studies to improve seeding techniques and to control noxious plants; (d) mountain meadow research should be continued and expanded to determine soil relationships, most productive grasses and legumes, optimum use of irrigation water, nutritional value of various forages, and relative advantages of pasturing as opposed to use of the same area for winter hay production.

(4) Studies of water resources on mountain ranges should include irrigation practices, consolidation of existing systems, reducing water losses, underground storage, measures to slow runoff, relative costs and benefits of water, resolving conflicts not only between range operators but also between grazing and other uses, influence of rodents and other animals on the watershed, and control of water loving plants.

(5) As in all other phases of resource use and development, education of the general public for wiser use of the mountain range resource is essential.

(6) Certain incentive and regulative needs are apparent: (a) equitable taxation on privately-owned rangelands to encourage proper use is desirable; (b) recognition of the downstream benefits by improvement of the quality and quantity of water through financial participation is desirable; (c) as in plains range resources, allocation of a portion of state lease income should be devoted to the improvement of mountain rangelands; (d) a mineral resource development program should be adopted that takes into consideration erosion hazards and possible surface damage; (e) a state act similar to the Colorado Wind Erosion Act is desirable to provide protection of the public health and welfare from destructive land use.

Part VI--Forestry

Colorado forests play a vital part in the state's economy. They provide recreational opportunities for out-of-state visitors, serve as the principal source of water for Colorado and other western states, provide summer feed in the form of grass and shrubs for thousands of livestock and a timber supply as yet not fully developed, but capable of supporting a greatly expanded wood products industry.

Recommendations

Development of a long range program for Colorado forest lands must be based upon improved legislation and expanded research. There is an urgent need for the following:

(1) Legislation to:

(a) Define the scope of the program.

(b) Identify responsibilities in light of current demands on the resource and facilities with which to do the job.

(c) Revise existing statutes governing forest fire protection and taxation.

(d) Provide means and responsibility for improved forest management.

(2) Research to develop new uses for small size trees or to find more economic processsing methods for the manufacture of existing products should be undertaken.

(3) More economic methods of logging, particularly on steep slopes to increase use of timber should be developed.

(4) Studies should be made to develop uses for less valuable tree species such as aspen, scrub oak, cottonwood, pinon pine and junipers.

(5) More uses for wood waste should be developed, such as mulching material, bedding material, briquets for fuel, etc.

(6) Research into the spread of disease and insect infestation in our forests is essential.

(7) Expanded weather research to improve forecasts of fire danger is desirable.

(8) Studies of cutting and thinning systems to improve growth, quality and reproduction are needed.

(9) A better understanding of natural regeneration is needed in order to promote quicker stocking of cut-over and fire or insect-killed stands of timber.

(10) Long-term studies in forestry genetics are desirable.

INTRODUCTION

This report attempts to assemble available information and an analysis of basic problems of significance to the State Department of Natural Resources. The information is based on the department's policy assignment for the conservation and development of agricultural and forestry resources. The report consists of two parts--the first deals with agriculture, the second with forestry. Included for each are (1) descriptions of present resource use; (2) summaries of current state and federal programs affecting use; (3) identification of areas of resource-use problems and conflicts; (4) reference to data and studies that provide more detailed information of possible pertinence; (5) suggestions regarding additional information, studies, and research needed; (6) suggested state policy, including proposed implementation and suggestions for better integration between the state and federal governments in reaching resource-use objectives.

Philosophic Assumptions

Goal: Use of agricultural land and forests in a manner that will return maximum benefits to Colorado citizens over a long period of time.

Test of Legitimacy of State Action: In keeping with the traditional concept of American free enterprise, the freedom of the individual to own and utilize resources as he sees fit should be paramount except where public interest to the contrary is clearly established. In many cases, the resource use pursued by citizens will be consistent with resource-use objectives of the state. Under these conditions, no state action is called for. For state

owned land, it is obvious that policies and action in the public interest take precedence.

Circumstances that Justify State Action: In some instances, freedom to use resources as the individual may choose conflicts with the attainment of the greatest good for citizens. Some common causes of conflict are:

1. Ignorance or lack of information on the part of users.
   Some individuals may be poorly informed concerning the consequences of practices they employ in using resources. As a result, they may fail to provide the resource protection deemed necessary by the state. The same practices may lessen their chances of surviving as a going concern.
2. Shorter planning horizon of individuals.
   Economic considerations tend to force individuals to plan for much shorter periods of time than a public body such as a state or a nation. An individual often must strive for maximum profits during the next season, or possibly within five years. On the other hand, a state or nation must plan for generations or centuries. This distinction becomes critical when dealing with exhaustible resources. It may also be pertinent where actions by individuals jeopardize productive capacity of a removable resource. State policy would seek to compromise at that point where individual action must be curbed in the long-run public interest.
3. Separation of costs and benefits in relation to actions taken.
   Cases arise under private ownership and control of

productive resources where one individual may reap damage from a production practice while another receives short-run benefits. For example, an upstream farmer may increase current income by planting intensive intertilled crops on an erosive soil. The resulting flood damage may be borne by other individuals whose land lies below.

4. A fourth cause of conflict, and one of growing importance as the population increases and industrialization progresses involves possible alternative uses.

   Super highways, recreation developments, and industrial and municipal water needs are only a few of the alternative resource-use conflicts that will become increasingly apparent. Soundly conceived policy will be necessary if the public interest is to be served.

Principal Means of State Action: The state has three principal avenues for achieving the desired degree of compromise when results of individual actions conflict with resource-use goals. Application varies in cost, effectiveness, and the degree to which individual freedom of action is limited:

1. Research and Education

   Where mal-use of resources is a result of lack of information (or of misinformation), the state may undertake remedial research and education. Results are often slower than by other means. But the efficient operation of a democratic and free enterprise social system presupposes an enlightened citizenry and the least regulatory action consistent with achievement. Accordingly,

research and education as opposed to any such regulatory measures, should be given priority consideration wherever this approach shows promise of effective results.

Colorado State University is the logical state institution for assignment of state research and education activities for land, water (to the extent that irrigation demands its use), forest, and fish and game. Its Experiment Station was established for this purpose and stands ready to undertake assignments in these fields whenever a request to do so is underwritten by necessary funds. In like manner, the Extension Service of the institution has long been organized to carry an educational program throughout the state. Extension helps achieve local adaptation of experimental results, and organizes programs that will acquaint people with those results.

Much of the more specific "look ahead" suggestions in this report deal with areas of needed research and education because (1) private-ownership management privileges rightfully limit drastic means of state action to protect public interests (at least to the degree already suggested when discussing the test of legitimacy of state action) and because (2) of the over-riding relative influence of federal programs (later discussed) in the fields of agriculture and forestry.

Incentives

Through its power to tax, license, and channel its disbursements, the state can provide incentives to those who act in a manner that will conserve or develop resources.

Severance taxes and differential property assessment rates on plowed and grazing lands are examples of incentive devices that can be used to help guide resource use.

3. Permissive and Restrictive Measures

The power to pass restrictive legislation to promote the general welfare is the most direct, powerful, and quickest remedial tool in the state's possession. Cities and municipalities pass urban zoning laws to promote the orderly development of a city. A beginning has been made toward zoning beyond the urban centers. Colorado has an enabling rural zoning act for curbing abuse of rural lands. The state also has a wind-erosion control law.

An example of permissive power is found in hunting regulations for orderly harvesting of wildlife.

Achievement of the resource-use goal of the state will depend in large measure on the wisdom shown in using the tools of research, education, incentives, and controls.

Economic Importance of Agriculture

For many years agricultural production accounted for an average of 55 percent of all newly-created wealth in Colorado. Rapid strides in manufacturing and increased oil, gas, and uranium activities undoubtedly will reduce this percentage in years to come. In 1956 (the second poorest income year in ten for agriculture), manufacturing displaced agriculture for the first time as the number one industry of the state. Although the relative importance of agriculture's contribution to Colorado's prosperity may decline with time, in an absolute sense the food it provides for a growing population becomes more important than before. Conse-

quently, the protection and optimum development of our agricultural land resources is imperative and worthy of earnest resource-policy study.

Some idea of the tremendous importance of agriculture to the economic life of Colorado can be obtained from selected statistics:

Income from sale of products: The average cash income from farm marketings for the ten-year period, 1947-56, was $500 million, or about one-fourth of the total income payments from all sources in Colorado over the same period. (This round figure sum of $500 million is coincidental. It is the actual average to the closest million.) Approximately 40 percent of agricultural income has come from the sale of crops; 60 percent from the sale of livestock. Government agricultural payments of various kinds have averaged an additional $10 million. Thus, sale of farm products every year prior to 1956 has been the greatest single source of income in Colorado.

Number of Farms and Farmers: Numerically, both the number of farms and the number of farm people have been declining. Nevertheless, the role of agricultural producers and production is of paramount proportions as a key generative force in maintaining a healthy state economy.

In 1954, there were 40,749 farms. There was no census that year, but if the rural farm population bore the same relationship to the number of farms as was true in 1950, the farm population was approximately 177,000 or about 12 percent of the total state population.

Farmers as Customers: In addition to family-purchase requirements typical for city dwellers, farmers must make considerably

higher-than-average capital expenditures. Mechanization has increased these requirements dramatically. A well-equipped farm often has machinery costing between $25,000 and $30,000. Depreciation and obsolescence require replacement at least every ten years. The most recent census of agriculture shows 61,920 tractors, 14,304 combines, and 48,653 trucks on Colorado farms. These are only the most common farm machines. Farm buildings, apart from dwellings, often exceed the dwelling value. Fencing is a costly investment.

Operational expenses are also high. Gas, other machine fuel, and oil expenditures cost Colorado farmers about $24 million in 1954. The livestock and poultry feed bill was $64.5 million; fertilizer cost $4 million.

Farmers as Employers: The total work force on Colorado farms (family and hired workers) in October, 1954, was 96,043 persons. The year's bill for hired labor came to $33.6 million; in addition, $9.3 million was paid out as machine hire.

Farmers--A Labor Pool: Farm people make up a significant labor pool to supplement labor available in town and city. The 1954 Census of Agriculture reports that almost 10,000 farm operators worked off the farm 100 days or more. Over 8,000 more worked off the farm one to 99 days. This does not take into account large numbers of wives and children who hold city jobs.

Indirect Contributions Exceed Direct Benefits: Farm production is a generative force for economic wealth and activity far exceeding the initial value of products raised. Without agriculture, few if any of the state's smaller towns and cities would continue to exist. Agricultural products also loom large as business

creators and stimulants in our large population centers. The raw materials supplied are the basic ingredient for "big business" meat packing plants, sugar factories, dairy manufactures, milling and baking establishments, and canning factories. They contribute in substantial measure to railroad and trucking volume. Add the purchasing power involved in all the processing and marketing steps between farm value and retail price to these "one step removed" benefits and it quickly becomes evident that the indirect benefits stemming from the basic and renewable natural resource far exceed the direct contribution.

Tax Base--Agriculture Plays a Stabilizing Role: Assessed value of real property in Colorado is roughly equivalent to 35 percent of current sale value. On this basis, assessment of strictly agricultural property in 1955 at $537.6 million indicates assets worth over $1.5 billion. Agricultural items represented about 19 percent of the grand total net state assessment of $2.87 billion. Many individual counties rely heavily on agricultural property as a base for local government revenue. For example, about 77 percent of the real and personal property assessed in Custer County is found on farms and ranches.

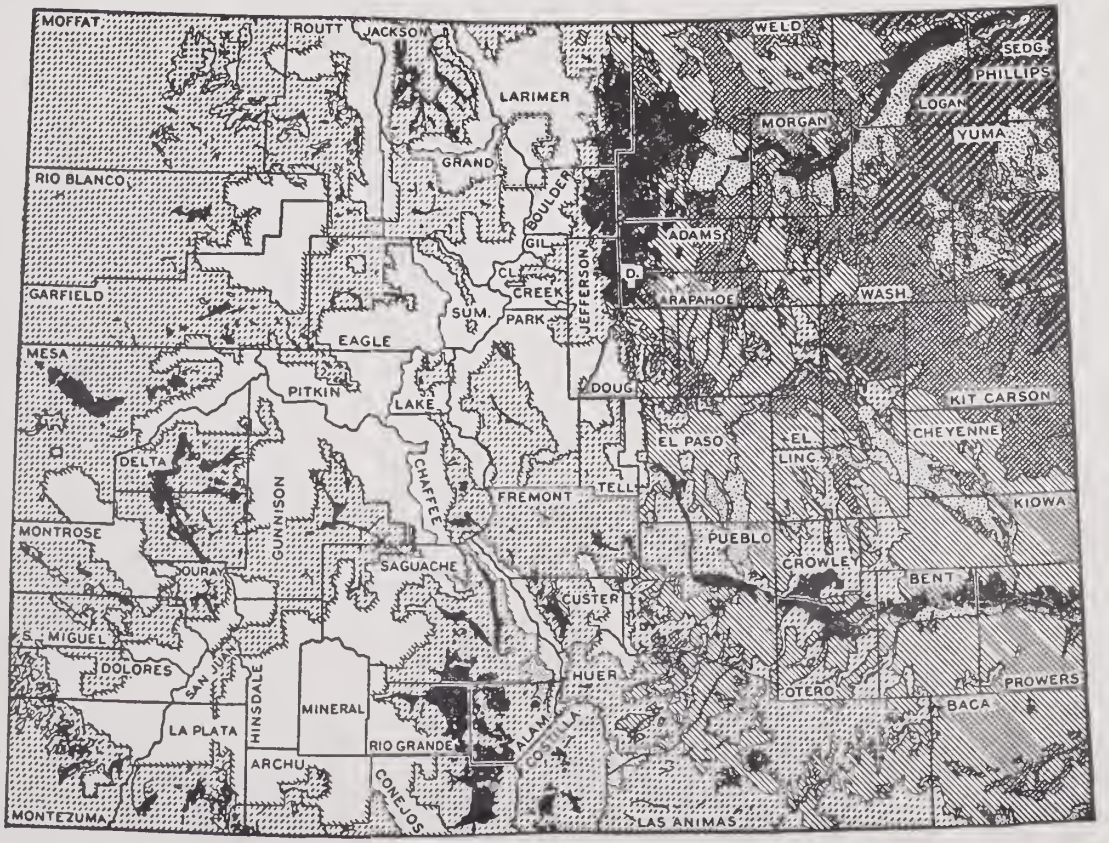
Agricultural Stability and Growth Vital: The extensive land resources of Colorado contribute to overall state economic growth and prosperity through agricultural production in greater relative measure than is true for the country as a whole. Much of the state is suited only for agricultural production. Food requirements of present and future citizens underline the cardinal importance of maintaining and improving this vital natural resource.

Land Classification

The Colorado Year Book, 1951-55, includes on pages 684-686 what is perhaps the most complete land classification currently available. A county-by-county statistical compilation is given. Agency sources used were the U. S. Bureau of the Census, State Tax Commission, State Land Board, U. S. Bureau of Land Management, U. S. Forest Service, U. S. National Park Service, and the U. S. Department of Defense. Ownership on the broadest classification basis is given as follows:

Land Ownership	Acres	Percent of Total State Acreage
Privately owned land (on tax rolls)	39,125,104	58.8
State-owned, school and other lands	3,162,438	4.8
County and Municipal owned land	284,861	0.4
Owned by the United States Government (Federally owned)	23,937,677	36.0
Total Land Area.	66,510,080	100.0

Another approach to land classification was made during the 1930's by the U. S. Department of Agriculture. This was the preparation of a map (see page I-10.) that located various types of land according to type of agricultural production, as well as all federally owned lands in the state. This classification is still useful as a rough guide for land-use capability and is included in every recent annual issue of Colorado Agricultural Statistics, published cooperatively by the Colorado Department of Agriculture and the Agricultural Marketing Service of the USDA.



LAND CLASSIFICATION OF COLORADO

- *Irrigated land*
- *First class dry farming*
- *Second class dry farming*
- *Third class dry farming*
- *Sand hills*
- *National forests*
- *National parks*
- *Grain crop land*
- *Grazing land*
- *Forage crop land*

U. S. DEPARTMENT OF AGRICULTURE

NEG. 32989

Implications of Population Increases

Colorado's population in 1950 was 1,325,000--an average of 12.7 persons per square mile. The 1957 population has been estimated at about 1,600,000 with rapid growth continuing. The recent rate of population increase in Colorado is about twice the national rate. Almost all the growth is occurring in urban centers. In planning the long-time use of land and water resources, due consideration for the future requirements of these added city dwellers is a "must." City growth, in some of these instances, is encroaching on highly productive cropland. This is particularly apparent in the Platte Valley and Arkansas Valley irrigated sections. More important in relation to future agricultural production limitation is the exceedingly rapid expansion in demand for water for domestic and industrial use.

Land Area of Colorado

The total land area of Colorado is 66,718,000 acres of which about 208,000 acres are water-covered. The state is seventh largest in the nation.

Topography and Climate

Colorado, far removed from any major source of moisture, has comparatively light rainfall with an average over the state of about 16.5 inches a year. Periods of adverse weather are generally sporadic and brief. There is a high percentage of clear days.

Within this broad overall picture there are, however, widely varying local conditions. These differences are due principally to variations in elevation which range from about 3,400 feet in the southeast where the Arkansas River leaves the state to mountain peaks which exceed 14,000 feet. Adapted phases of agriculture are carried on at all altitudes except in the highest mountain areas.

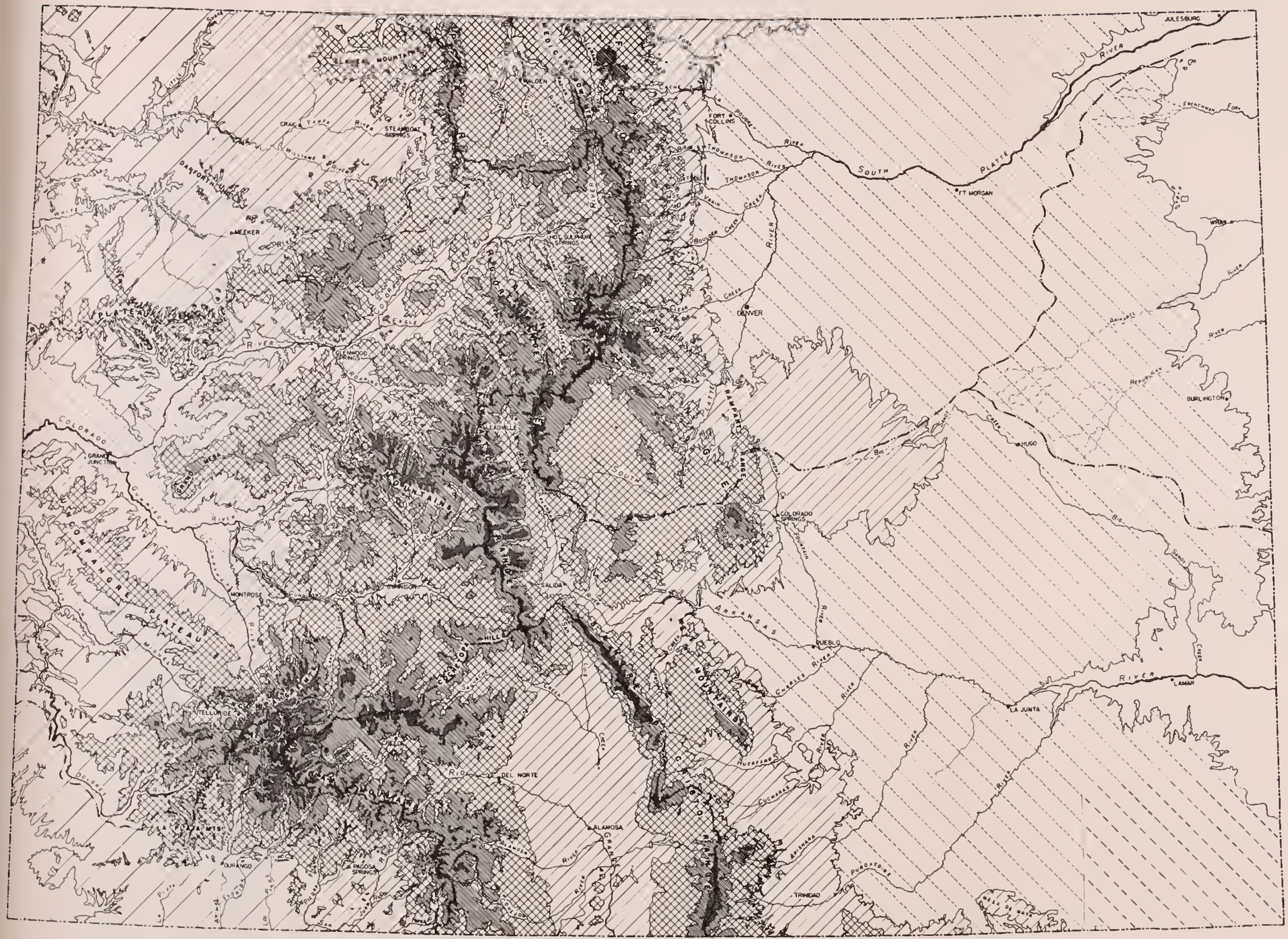
Terrain varies from exceedingly level land to rolling, steep, and even precipitous slopes. (See topography map, page I-13.)

Among the benefits from the alpine climate of the high mountain is the heavy snowfall occurring during the winter and spring months. This snow, melting in the spring and summer, provides irrigation water which makes possible bountiful agricultural production on land that otherwise would be semi-arid prairie.

Colorado is a crossroads for the various air masses found in the northern hemisphere. The state is located within the broad band of the temperate westerlies. As these west winds occasionally weaken, they are interrupted by intrusions of polar air masses from the north or tropical air from the south. Thus, Colorado may get air of varying characteristics from any of the following sources: (1) Cold, generally dry, polar air from the north and northwest; (2) cool, moist air from the Pacific Ocean; (3) warm, moist air from the Gulf of Mexico; and (4) dry, hot air from Mexico and the southwest desert of the United States.

Early fall and late spring freezes often shorten and vary the growing season in the east portion of the state. Since many of these abrupt changes do not cross the continental divide, the growing season in the lower valleys of the Western Slope is longer than in the east portion of the state. For example, Denver's growing season averages 164 days, Pueblo's 174, while Palisade and Grand Junction average 180 and 191 days respectively. These differences considerably affect agricultural production. (See growing season map, page I-14.)

Because behavior of the air masses is not consistent, a tendency toward grouping of years of subnormal moisture exists. Herein, perhaps more than with any other single factor, lies the basis of



Topography Of Colorado

Elevations Above Sea Level in Feet

- Below 4,000
- 4,000 - 6,000
- 6,000 - 8,000
- 8,000 - 10,000
- 10,000 - 12,000
- Above 12,000

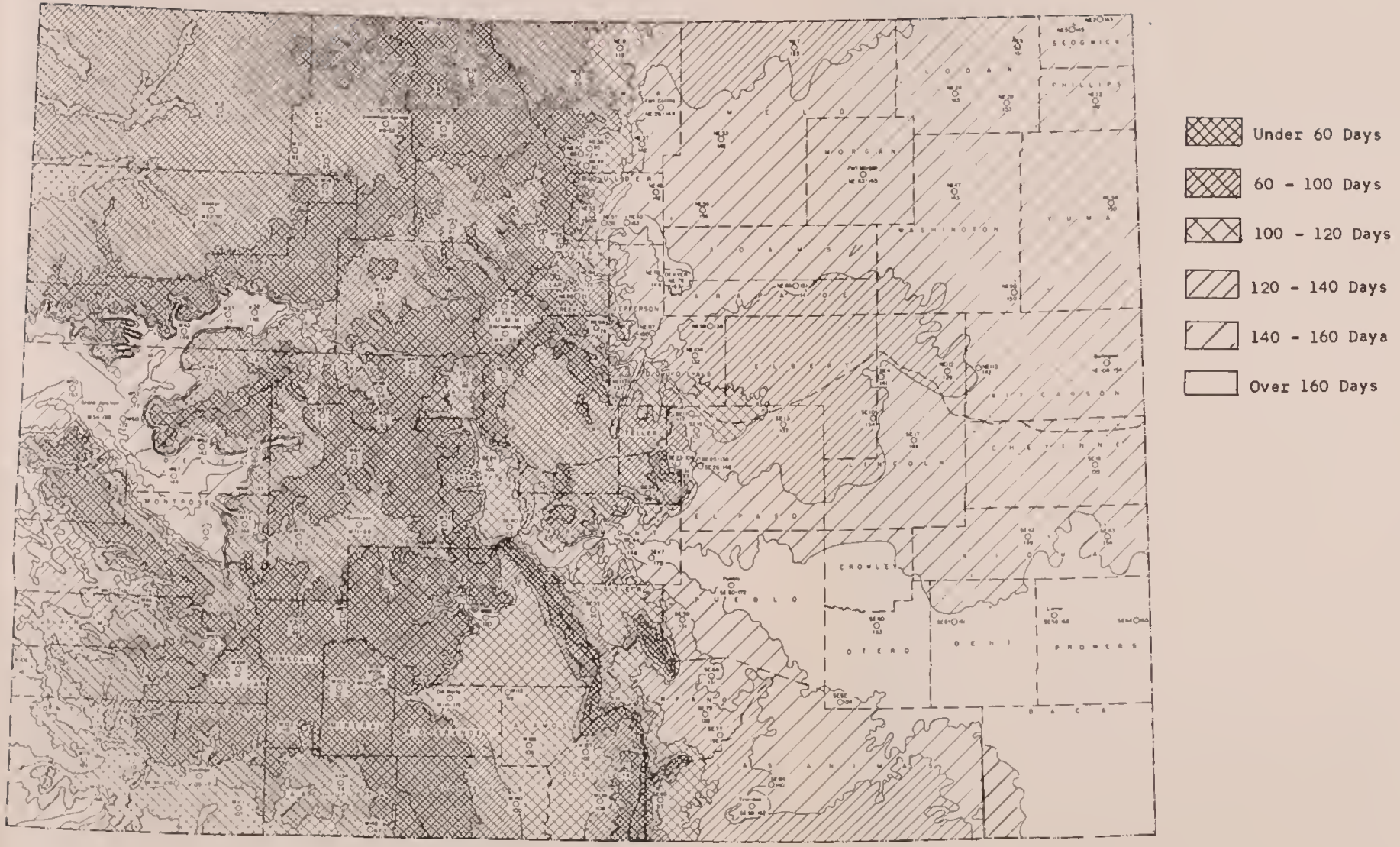
Continental Divide

Basin Divide

Sub-Basin Divide

Growing Season Map Of Colorado

(Showing Average Number Of Days Between Killing Frosts)



agricultural economic and resource-use problems, particularly in the plains area of the eastern slope.

Spring is the season when the moisture-laden air from the Gulf of Mexico most frequently works its way northward as far as Colorado. It is then that the eastern plains portion of the state receives its most general and heaviest rainfall. It is fortunate that most of the precipitation falls during the growing season for it sustains agricultural activities in all but the driest years. This gulf air also brings showers and thunderstorms that normally carry on into the summer. (See precipitation map, page I-16.)

Kinds of Agriculture

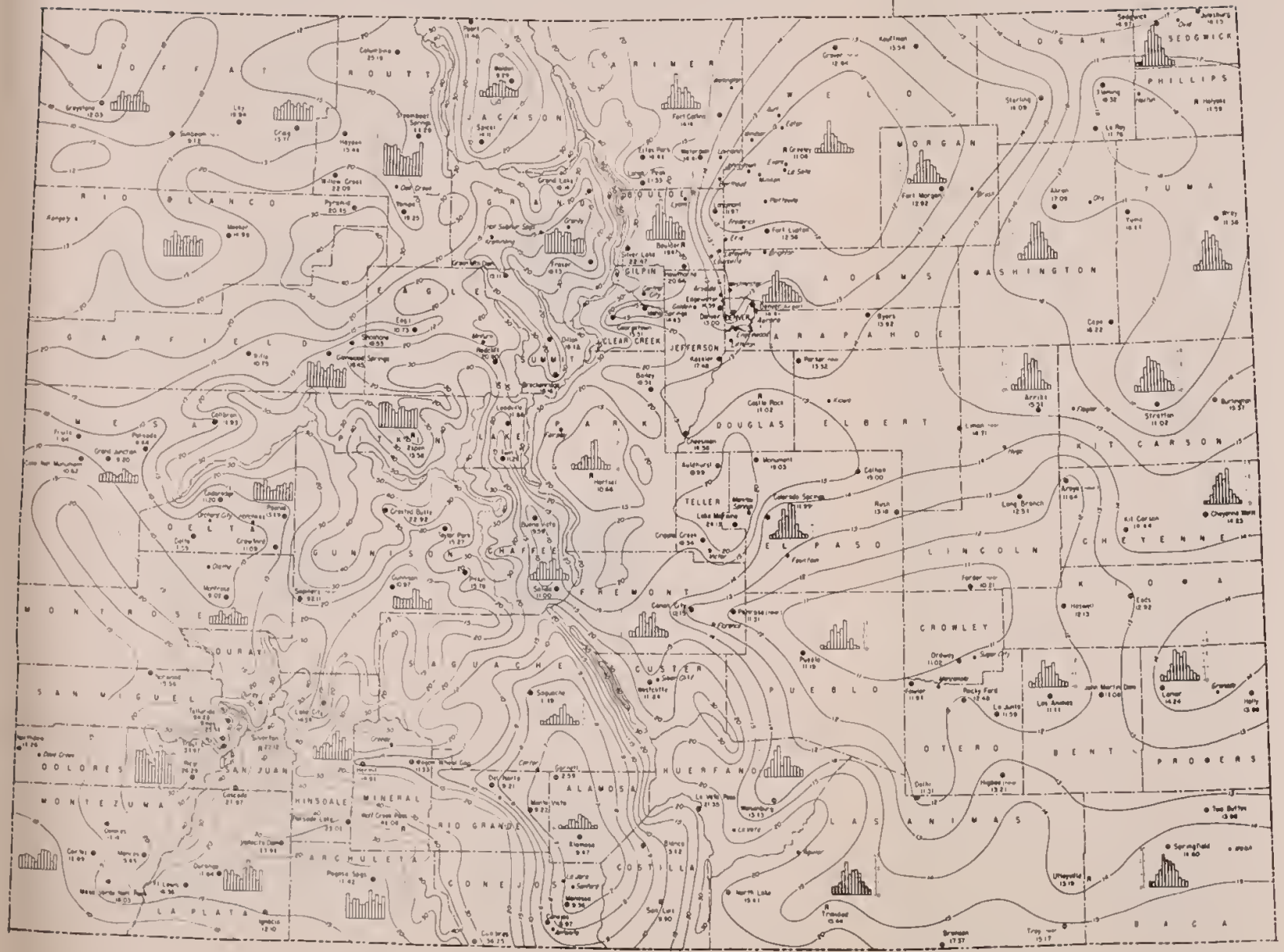
Conditioned in large measure by topography and climate, the variety of agricultural products in Colorado is second only to California. Products range through a wide selection of commercial vegetables to feed crops, cash crops like potatoes, dry beans, wheat and sugar beets, dairy products, eggs and poultry, sheep and wool, range livestock, and fed lambs and cattle.

Water available because of a heavy snow pack in the mountains permits abundant production by irrigation. Almost two-thirds of the value of all crops produced annually comes from irrigated acreage; this same acreage provides much of the feed for (1) the state's 150,000 head dairy herd, (2) the 575,000 cattle fed annually, and (3) the 585,000 lambs fed. Mountain irrigation is responsible for most of the winter feed provided some 500,000 head of livestock in that large section of the state.

The proportionately heavy reliance on livestock production as the "backbone" of the state's agriculture is shown by the 1954 farm income. 41 percent of the income came from the sale of cattle, calves, sheep, and lambs. (See also page I-17.)

DISTRIBUTION OF PRECIPITATION IN COLORADO

LINES WITH FIGURES INDICATE AREAS OF EDUAL AVERAGE ANNUAL PRECIPITATION, IN INCHES
BAR GRAPHS INDICATE AVERAGE MONTHLY PRECIPITATION, IN INCHES, OF DIFFERENT AREAS IN COLORADO



AVERAGE MONTHLY DISTRIBUTION OF PRECIPITATION

PRECIPITATION IN INCHES

J F M A M J J A S O N D

MONTH

0 1 2 3 4 5 6

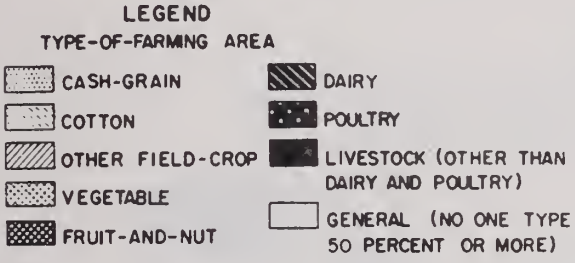
SCALE OF MILES

COLORADO STATE PLANNING DIVISION

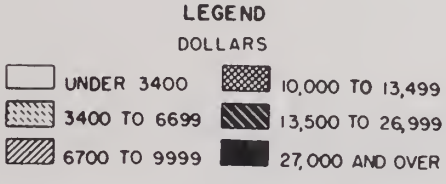
Measures of Value

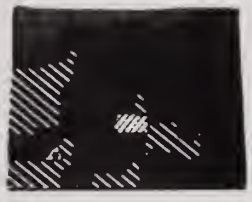
The graphs from the 1954 Census of Agriculture (pages 17 and 18) are helpful in obtaining perspective in some aspects of value measures for agriculture as they apply to county units.

Type-Of-Farming Areas, Based on Type Accounting For 50 Percent Or More Of Commercial Farms, 1954

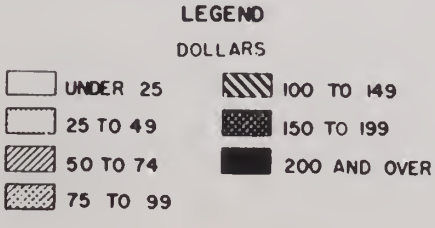


Average Value Of Land And Buildings Per Farm, 1954





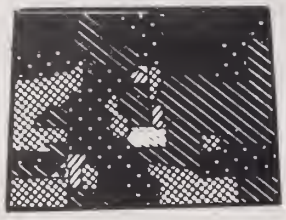
Average Value Of Land And Buildings Per Acre, 1954



Average Value Per Farm Of Farm Products Sold, 1954

LEGEND
DOLLARS

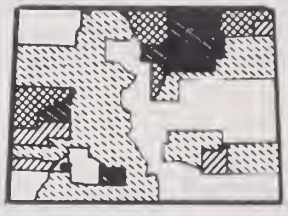
- UNDER 1,300
- 1,300 TO 1,999
- 2,000 TO 3,399
- 3,400 TO 5,399
- 5,400 TO 7,999
- 8,000 TO 12,000
- 13,000 AND OVER



Average Value Of Farm Products Sold Per Acre Of All Land In Farms, 1954

LEGEND
DOLLARS

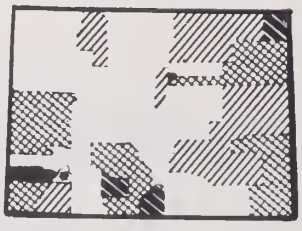
- UNDER 5
- 5 TO 9
- 10 TO 14
- 15 TO 24
- 25 TO 49
- 50 TO 74
- 75 AND OVER



Value Of All Crops Sold As A Percent Of All Farm Products Sold, 1954

LEGEND
PERCENT

- UNDER 20
- 20 TO 39
- 40 TO 59
- 60 TO 79
- 80 AND OVER

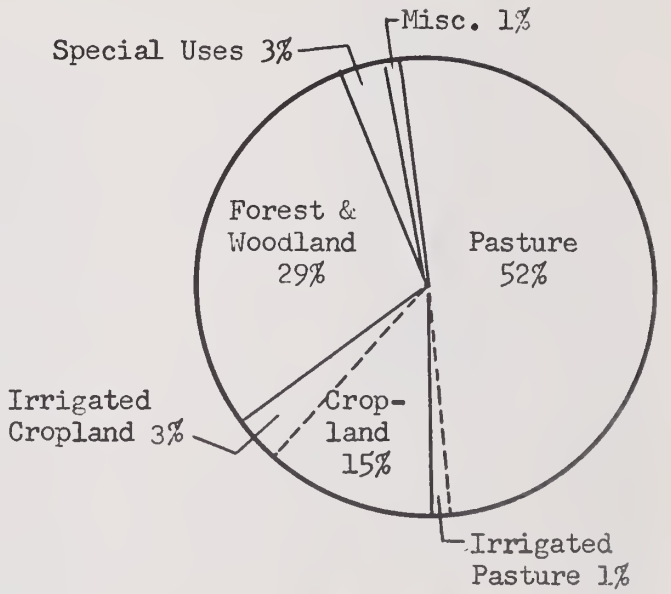


Major Uses of Land

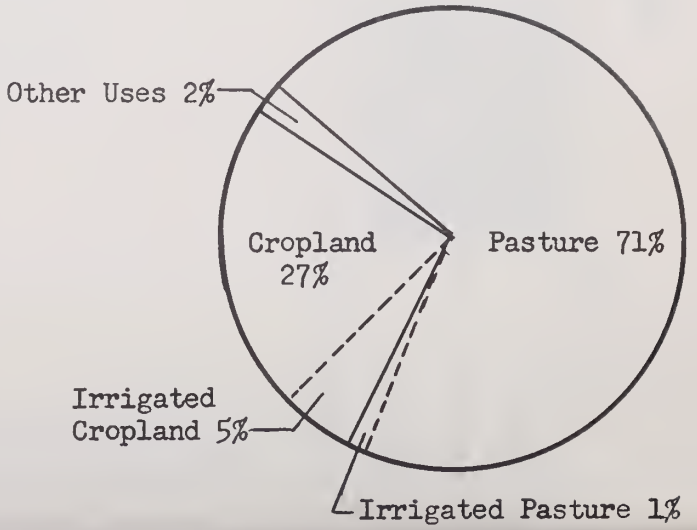
The USDA publication, Major Uses Of Land In The United States, issued in January, 1957, has been used as the basis for acreages referred to by type of use throughout this report. Relative acreages of different major uses of land are shown statistically and graphically on the following pages.

From: "Major Uses of Land in the United States", Agricultural Inf. Bull. 168 ARS, USDA, Jan. 1957

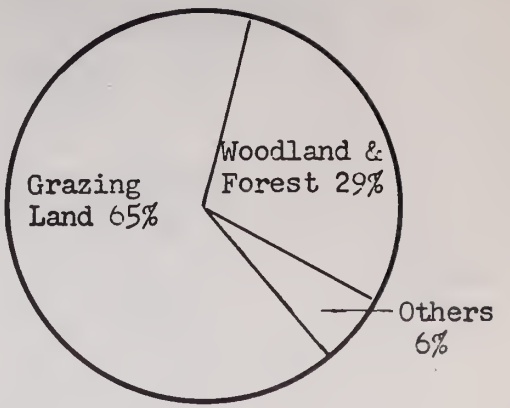
MAJOR USES OF LAND	ACRES	%
Cropland (all uses, except pasture)	10,249,000	15
Irrigated	(1,770,000)	(3)
Pasture, Cropland Pastured, and Grazing Land Non-Forested	34,245,000	52
Irrigated	(493,000)	(1)
Forest and Woodland	19,523,000	29
Special Uses (farm, urban, national defenses, public, highways, etc.)	1,977,000	3
Miscellaneous (marshes, sand dunes, bare rocks, etc.)	516,000	1
Total Land Area	66,510,000	100



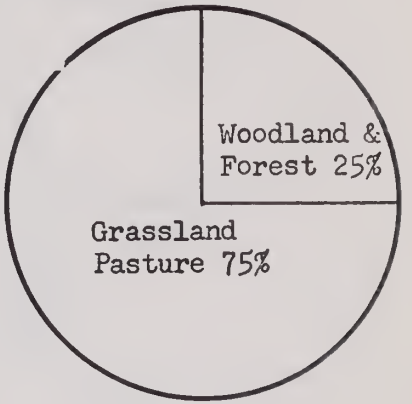
MAJOR USES OF LAND IN FARMS		
Cropland (all uses, except cropland pastured)	10,249,000	27
Irrigated	(1,770,000)	(5)
Pasture, Cropland Pastured, open permanent and woodland pasture	27,160,000	71
Irrigated	(493,000)	(1)
Woodland not pastured	169,000	--
Other (farmsteads, roads, lanes, ditches, waste)	807,000	2
Total (57.7% of total land area)	38,385,000	100



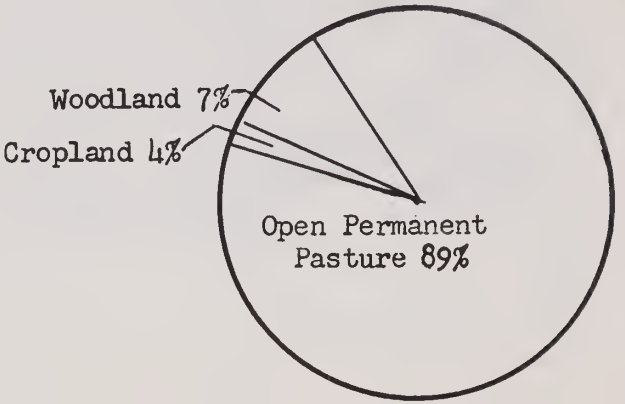
MAJOR USES OF LAND NOT IN FARMS	ACRES	%
Grazing Land Not in Farms (Mostly Nat'l Forest & BLM)	18,365,000	65
Woodland and Forest not grazed	8,074,000	29
Others (urban, nat'l defense, public highways, etc.)	1,686,000	6
Total (42.3% of total land area)	28,125,000	100



ALL GRASSLAND AND WOODLAND PASTURE AND GRAZING LAND		
Grassland Pasture and grazing land	34,245,000	75
Woodland and Forest pastured or grazed	11,280,000	25
Total	45,525,000	100



PASTURE IN FARMS BY TYPE OF PASTURE		
Cropland used only for pasture	1,008,000	4
Open permanent pasture	24,318,000	89
Woodland pasture	1,834,000	7
Total	27,160,000	100

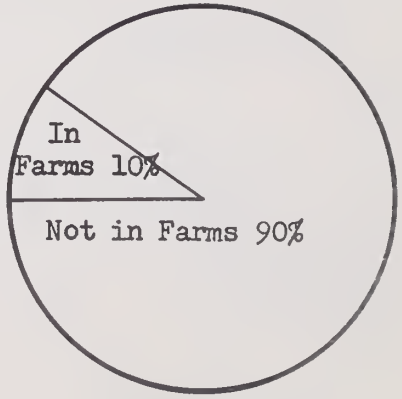


PASTURE AND GRAZING LAND IN FARMS AND NOT IN FARMS

	ACRES	%
In farms	27,160,000	60
Not in farms	18,365,000	40
Total	45,525,000	100

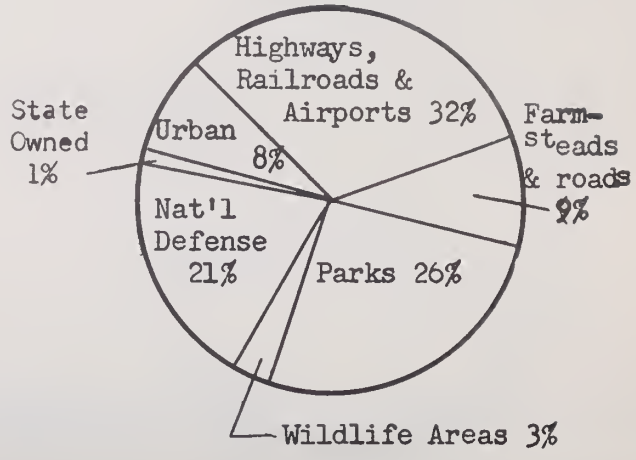
WOODLAND AND FOREST IN FARMS AND NOT IN FARMS

In farms	2,003,000	10
Not in farms	17,520,000	90
Total	19,523,000	100

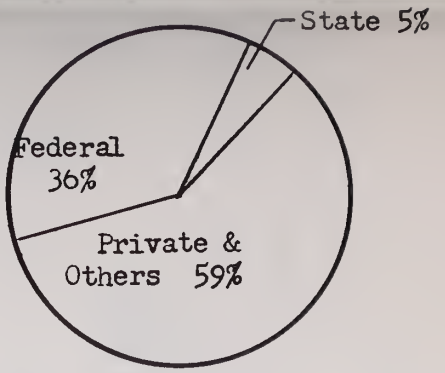


LAND IN SPECIAL USE AREAS

Urban	151,000	8
Highways, Railroads and Airports	693,000	32
Farmsteads, farm roads and lanes	172,000	9
Parks	518,000	26
Wildlife areas	67,000	3
National Defense	414,000	21
State owned institutions and misc.	16,000	1
Total	1,977,000	100

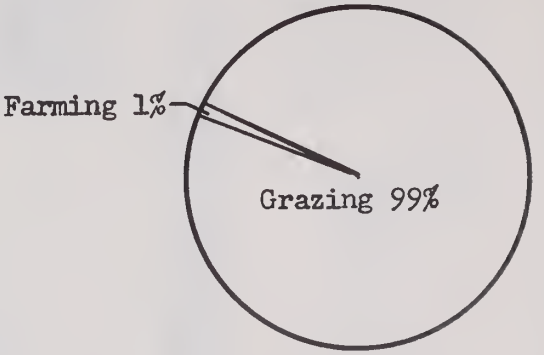


FEDERAL, STATE, PRIVATE AND OTHER LAND	ACRES	%
Federal	24,120,000	36
State	3,181,000	5
Private and others not owned by Federal and State Governments	39,209,000	59
Total	66,510,000	100

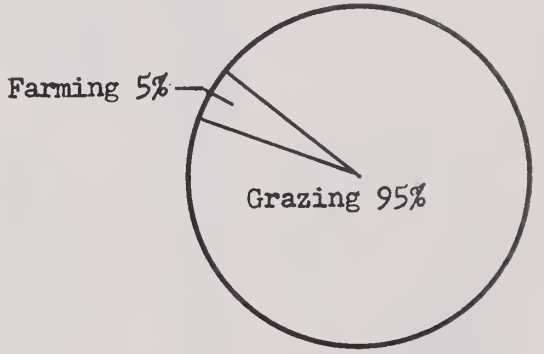


FEDERAL AND STATE OWNED LAND USED FOR FARMING AND GRAZING

Federal		
Farming	11,000	1
Grazing	15,355,000	99
Total	15,366,000	100

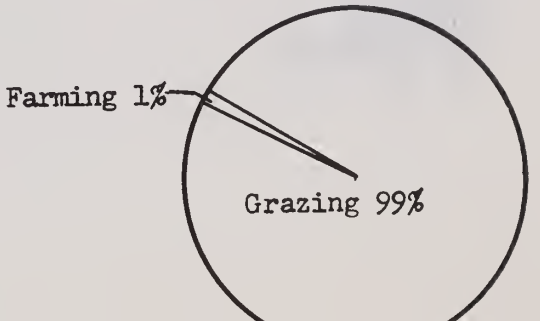


State		
Farming	143,000	5
Grazing	2,775,000	95
Total	2,918,000	100



INDIAN LAND USED FOR FARMING AND GRAZING

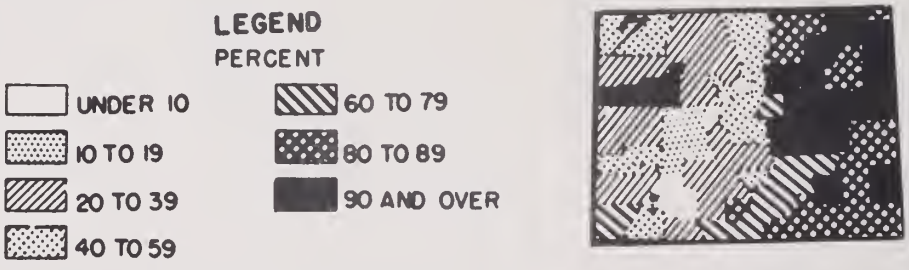
Farming	8,000	1
Grazing	685,000	99
Total	693,000	100



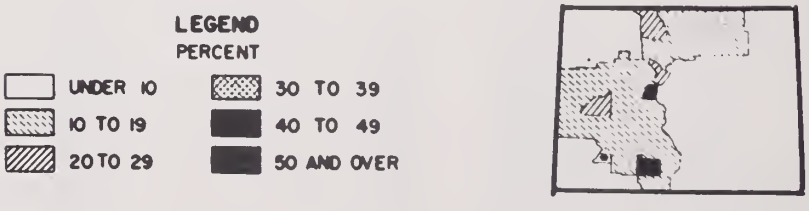
1954 Census Data--Land Use

Some useful aids in picturing land-use relationships and areas of occurrence are available from the 1954 Census of Agriculture - Volume II - General Report. These charts follow:

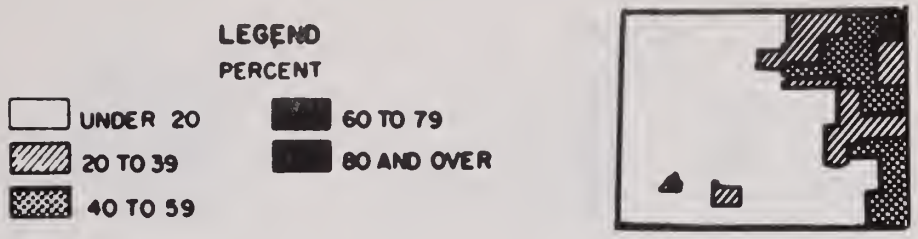
Percent Of Total Land Area In Farms, 1954



Irrigated Land As A Percent Of All Land In Farms, 1954

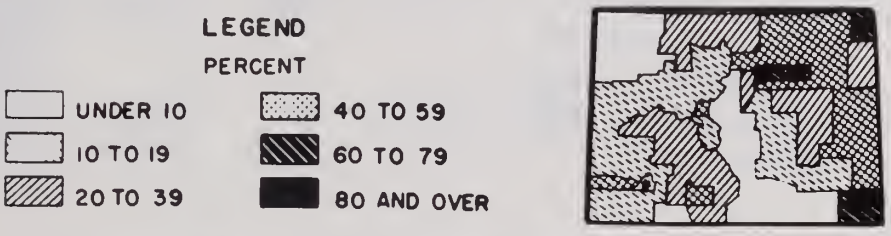


Cropland** As A Percent Of Total Land Area, 1954



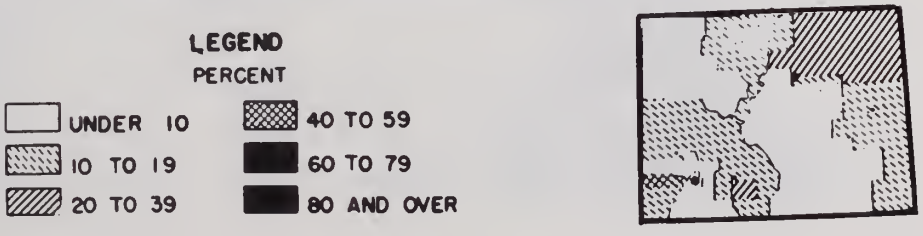
** CROPLAND HARVESTED, CROPLAND USED ONLY FOR PASTURE, AND CROPLAND NOT HARVESTED AND NOT PASTURED

Total Cropland** As A Percent Of All Land In Farms, 1954



** CROPLAND HARVESTED, CROPLAND USED ONLY FOR PASTURE AND CROPLAND NOT HARVESTED AND NOT PASTURED

Cropland Harvested As A Percent Of All Land In Farms, 1954

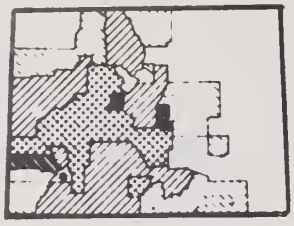


Cropland Used Only For Pasture As A Percent Of Total Cropland, 1954

LEGEND

PERCENT

- UNDER 10
- 10 TO 19
- 20 TO 29
- 30 TO 39
- 40 TO 49
- 50 AND OVER

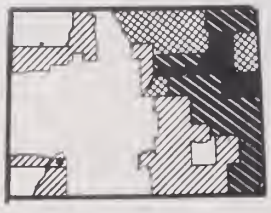


Cultivated Summer Fallow As A Percent Of Total Cropland, 1954

LEGEND

PERCENT

- UNDER 10
- 10 TO 19
- 20 TO 29
- 30 TO 39
- 40 AND OVER

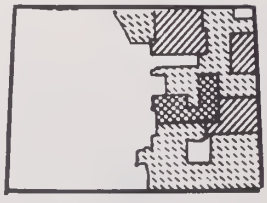


Land In Row Crops Or Close-Seeded Crops Grown In Strips For Wind Erosion Control As A Percent Of Total Cropland, 1954

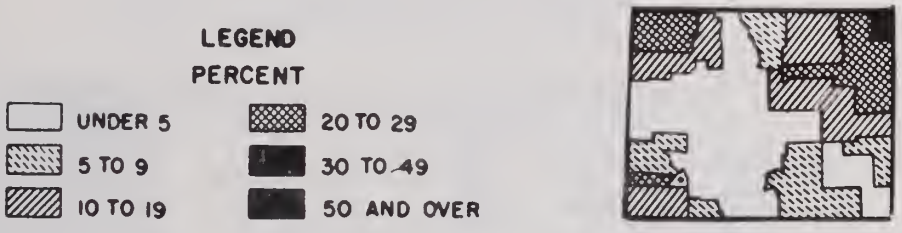
LEGEND

PERCENT

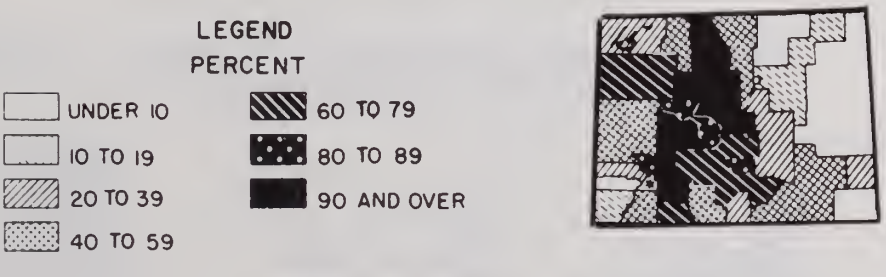
- UNDER 2
- 2 TO 4
- 5 TO 9
- 10 TO 14
- 15 TO 19
- 20 AND OVER



Acres Of All Wheat Harvested As A Percent Of Total Cropland, 1954

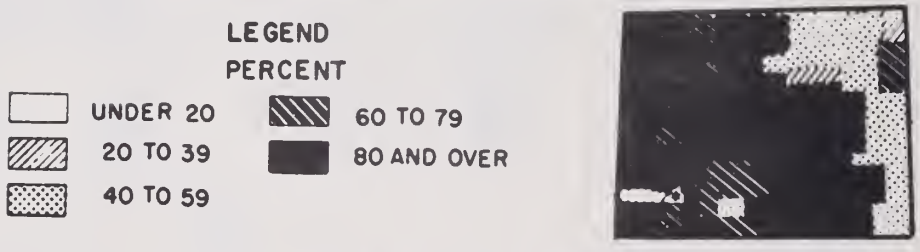


Hay Acreage** As A Percent Of Cropland Harvested, 1954



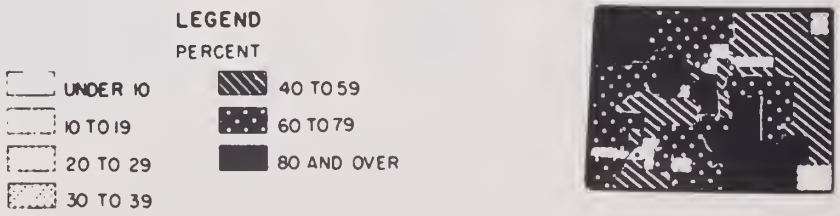
** EXCLUDING SOYBEAN, COWPEA, PEANUT AND SORGHUM HAY

Total Pasture** As A Percent Of All Land In Farms, 1954

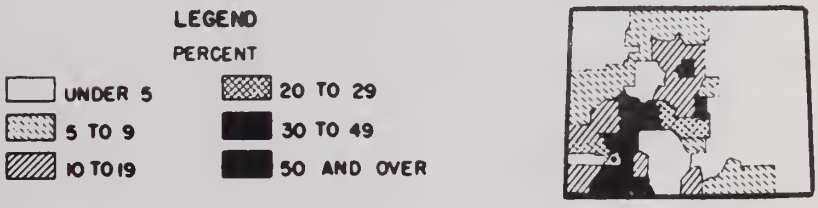


** CROPLAND USED ONLY FOR PASTURE, WOODLAND PASTURED AND OTHER PASTURE.

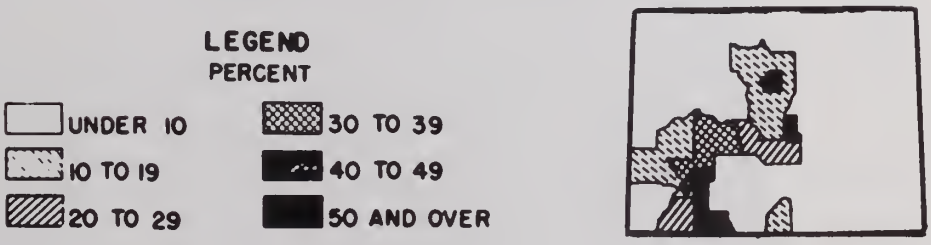
Other Pasture (Not Cropland And Not Woodland) As A Percent Of All Land In Farms, 1954



Total Woodland As A Percent Of All Land In Farms, 1954



Woodland Pastured As A Percent Of All Land In Farms, 1954



Aerial Photographs

Aerial photographs are a very effective means for studying land-use information. (See "map" of Sedgwick County, page I-31.) Principal difficulty encountered is cost and keeping up-to-date. But even several-year-old photos are useful for a fairly detailed land-use picture of any specific area. A complete index of available aerial photographs is kept by the Agricultural Stabilization and Conservation Service Office in the U. S. Custom House in Denver.

Land-Use Maps

County maps showing land use as of 1952 are available in the state office of the Soil Conservation Service in the U. S. Custom House, Denver. A state map developed from this base, or from more recent data, would be an extremely useful tool in developing resource policy.

Land Ownership Maps

The state office of the Soil Conservation Service has a complete county-by-county file of maps of land ownership. Data for these maps vary between 1948 and 1952. A "Public (federal, state, county, municipal) Land Ownership Map," dated April 1944, is available through the State Planning Commission and the State Water Conservation Board.

Land Resource Areas Map

Perhaps the most useful map available as an aid in relating land-use to land-resource protection is the "Land Resources Areas Map" prepared by the Soil Conservation Service. This map, if used as an overlay on a current land-use map of the same area and scale, would locate lands misused in relation to their use capability.

Aerial photographs such as this view of Sedgwick County provide effective land-use information.

A copy of the map and its legend explanation is included in the appendix of this report.

The land resource areas map has been prepared from various types of soil surveys made by federal and state agencies. It presents in a general way the most recent information available concerning the physical facts about the various land resource units. Land capability classification interpretation in this report has been limited primarily to areas where climatic environment is the principal factor in determination of maximum land capability.

The map submitted with this report is presently being revised and refined. The revision consists mainly of minor changes in the land resource unit boundaries.

Soil Surveys

The Agronomy Section of the Colorado Agricultural Experiment Station at Colorado State University was designated (by a memorandum of understanding subscribed to by all federal and state agencies in 1950) as the clearing office for all soils surveys made by agencies engaged in soil survey work. The Soil Conservation Service has available a "Progress of Soil Survey Map." The map is brought up to date each year.

Background Information Work Under Way

When completed, a program recently initiated by the USDA should provide useful land and water resource development guides.

USDA Memorandum No. 1396 issued by Secretary of Agriculture Benson establishes a national inventory of soil and water conservation needs. It further requires all agencies of the department--especially those concerned with land use, soil and water

conservation, and the management of land resources--to contribute and participate in the inventory. The Soil Conservation Service is the assigned leader. This inventory is being undertaken to satisfy a constant requirement for current information on conservation needs, information that will aid in planning for adequate continued beneficial use of the state and nation's soil and water resources. The inventory provides a systematic nationwide collection of facts regarding those resources, the problems in their use, and an estimate of the measures necessary to maintain and improve them.

Agency Programs Related to Land and Water Use

A number of federal and state agency programs affecting the soil and water resources of Colorado are now in operation. Some are primarily federal in nature, others primarily state, and still others involve various types of joint effort and inter-action. Any attempt to plan a program of resource use must involve an evaluation of agency programs in order to take full advantage of the combined potential of all such programs with a minumum of conflict and duplication.

Federal Agency Programs Related to Land and Water Use

Soil Conservation Service

A federal agency, the Soil Conservation Service is primarily an action agency designed to provide technical assistance to farmers and ranchers in accomplishing their individual conservation programs. This assistance has been primarily within soil conservation districts, but new legislation has broadened the responsibilities of the SCS to include involvement in small watershed programs. The SCS is also a cooperator in several soil and water resource programs such as soil surveys.

Within the limits of funds and manpower, the SCS provides technicians to assist soil conservation districts. These technicians, at the request of landowners, provide a complete inventory of the individual's physical resources of soil and water, the present pattern of use, and problems of erosion and fertility. Then, in consultation with the landowners, the technicians work out long-range conservation programs for individual farms.

National policy offers that soil and water conservation be accomplished through federal, state and local cooperation. In the federal establishment, the Department of Agriculture is responsible for administering most of the national soil and water conservation programs and the Soil Conservation Service is the technical soil and water conservation agency of the Department on private lands. In accordance with the national policy of federal-state-local cooperation, the activities of the Soil Conservation Service are carried out in cooperation with Soil Conservation Districts and with state and other local agencies.

In Colorado the most important legislation providing for this needed cooperation is the Colorado Soil Conservation Act. This act establishes the State Soil Conservation Board and provides for the formation of Soil Conservation Districts.

The state board has broad powers to promote the organization of Soil Conservation Districts and to cooperate with and assist districts in accomplishing their authorized objectives. The board is presently carrying out these functions. One important exception is that the board cannot discharge its authorized function of furnishing financial assistance to Soil Conservation Districts because state funds have not been made available for this purpose.

In this connection it should be noted that in a substantial majority of states financial assistance to Soil Conservation Districts through the use of appropriated state funds is already an established policy. There is a steady increase in the number of states in which this policy prevails, as well as an increase in the level of state appropriations. The purposes for which such funds may be used are also being broadened.

Until recently, state funds made available for assistance to Soil Conservation Districts have been considered as grants. Now there is evidence that some states are considering making money available as loans. During the 1956 sessions of the Virginia legislature, the State Soil Conservation Committee was authorized to offer as a gift or a loan financial and other assistance to Soil Conservation Districts. Direct appropriation for these purposes was in the amount of $140,980.

Enactment by the Congress in 1954 of the Watershed Protection and Flood Prevention Act established an additional area of federal-state-local relationships in the national policy concerning soil and water conservation. The Act was amended in 1956 and the effect of the amendment was to further broaden the area of federal-state-local relationships. The new policy includes flood prevention and the conservation, development, utilization and disposal of water.

Passage of the Act (Public Law 566) brought about a terrific impact on state and local agencies in a very short period of time and gives rise to the possible need for additional powers for State Soil Conservation Boards and Soil Conservation Districts. This is understandable in light of three basic concepts: (1) Under the Watershed Protection and Flood Prevention Act, each project is a local undertaking with federal help, not a federal project with local help; (2) Work in a watershed project typically is that of extending and adding to the activities now being carried out in Soil Conservation Districts; and (3) states are required by the federal act to participate, at least administratively, in the development of watershed projects.

Briefly, the powers needed or considered desirable in the development of watershed projects pertain to: (1) Local costs and the right of eminent domain with regard to the obtainment of lands, easements and rights of way in connection with structural and other works of improvement; (2) the local share of costs of construction; and (3) local responsibility and costs in connection with maintenance and operation of works of improvement. In the nation as a whole, states are responding to the new national policy by adjusting their own policies, enacting new or amendatory state legislation and adjusting the functions of state agencies concerning soil and water conservation.

The Long-Term Conservation Program for the Great Plains

This is another program to be administered by the Soil Conservation Service under Public Law 1021, 84th Congress. It provides for a complete conservation plan for the farm which would serve as a basis for a contract with the Department of Agriculture whereby the farmer is assured of cost-sharing and technical assistance for conservation practices enumerated in the contract. These contracts may cover a period of years but not beyond December 31, 1971. This program, it is believed, will tend to provide assistance in adopting conservation practices in a more organized and unified manner than has been possible under other agricultural programs.

Since the Great Plains Conservation Program has not yet been put into operation, accurate appraisal of its potential cannot now be made.

Current Soil Survey Program

The soil survey program in Colorado is carried on cooperatively between federal agencies and the Colorado Agricultural Experiment Station. The principal federal agencies presently engaged in this work are the Soil Conservation Service, Forest Service and the Bureau of Reclamation. Soil survey programs now in progress or planned in the near future that will supplement current data are listed in the appendix.

Land Resource Area Map--Colorado

A land resource area map has been prepared from various types of soil surveys made in the state by federal and state agencies. It presents, in a general way, the most recent information available concerning the physical facts about the various land resource units in the state. Land capability classification interpretation in this report has been limited primarily to those areas where the climatic environment is the principal factor in the determination of maximum land capability.

The map submitted with this report is presently being revised and refined. The revision consists mainly of minor changes in the land resource unit boundaries. It will be available at a later date. Map and descriptive legend are found in the appendix.

Agricultural Stabilization and Conservation Program

In broad terms the ASC program is one of providing incentives to the individual farmer on either a completely voluntary or on a regulated basis to bring about desired action through financial inducements. As in the case of SCS, the ASC program is a federal-state-local type of operation. The over all federal program is administered within the state by means of locally elected county committeemen who function under state leadership. Specific programs of ASC are:

Agricultural Conservation Program: The national agricultural conservation program of the ASC has been developed on the basis of the following general principles:

1. The intention is to confine application to soil and water conservation practices on which federal cost-sharing is most needed in order to achieve the maximum conservation benefit.
2. The state and county programs are designed to encourage those soil and water conservation practices which provide the most enduring benefits.
3. Cost will be shared with a farmer or rancher only on satisfactorily performed soil and water conservation practices for which federal cost-sharing was requested by the farmer or rancher before conservation work was begun.
4. The rates of cost-sharing in a county or state are to be the minimum required to result in substantially increased performance of needed soil and water conservation practices.

The state ACP program is developed by the state ASC committee, the state conservationist, and the forest service official having jurisdiction of farm forestry in the state. Representatives of the land-grant college, Farmers Home Administration, State Agricultural Extension Service, and the State Conservation Board also counsel in deliberations on the program.

Acreage Allotments: Wheat is the only crop in Colorado for which national acreage allotments are established. These allotments are based on previous crop history, percent of the farm in cultivation and suitability of the soil for the production of this crop. Of these factors, crop history has been the dominant consideration. There has been a tendency over the years for farmers to seed as many crop acres to wheat as possible in an effort to establish a higher crop history average. In the eastern part of the state, attractive price supports, coupled with a desire for larger allotments, have encouraged many farmers to plow up native grass and seed the land to wheat. In some instances the land so plowed was highly erosive and unsuited to continued crop production.

Soil Bank: The Soil Bank program is divided into two parts. The Acreage Reserve is intended as a short-time measure (three years) to further control the production of surplus crops. (Wheat is the applicable crop in Colorado). Rental payments are based on a normal yield established for each farm at the rate of 60 percent of support price. This results in an average payment for participating wheat land in Colorado of about $18 an acre. The payment constitutes rental by the government of a portion of the wheat allotment acreage. Participation is voluntary.

The Conservation Reserve is a rental payment for cropland which is to be re-seeded to permanent grasses and legumes, trees or other long-time conservation uses. These contracts extend for periods ranging from three to 15 years, depending upon the type of practice to be employed. In addition to the rental "fee" cost sharing is undertaken on cover crop establishment.

The Soil Bank program has not been in operation for a long enough period of time for its effects to be evaluated fully.

Farmers Home Administration

Loans for Soil and Water Conservation: Farmers and ranchers who are unable to obtain the necessary credit at reasonable terms and conditions from private or cooperative sources may borrow funds from FHA to pay the cash costs of making improvements directly related to soil conservation, water development and similar needs. This includes such improvements as construction and repair of terraces, dikes, ponds, canals for irrigation, land leveling, irrigation structures and erosion control structures; also, pasture improvement such as brush removal, leveling, fencing, well drilling and the purchase of pumps and other irrigation equipment.

The loan program is made up of three main classifications:

(1) Operating loans for the general purpose of financing farm operating expense for crop and livestock production, (2) farm ownership loans for purchase of farms by farm tenants or farm laborers, and (3) water facility loans for water development.

Water facility loans are made to individuals for domestic wells, stock wells, stock ponds, irrigation wells, irrigation structures, and other types of needed water facilities.

Loans are also authorized to mutual water companies, districts, or other associations for construction of irrigation systems, domestic water systems, or for the rehabilitation of such systems. These loans may be up to $100,000 to any one association for a 40-year period or the life of the facility, whichever is less. The interest rate for these loans is 3 percent.

Great Plains Credit Program: Under the Great Plains credit program, assistance is provided to eligible farmers and ranchers in officially designated drouth counties to enable them to make adjustments in their farming operations when necessary for proper land use and to meet essential operating expenses.

Borrowers will be expected to carry out farming practices that are consistent with good land use for the area. When adjustments in farming practices are needed, a detailed farm and home plan will be prepared and management guidance will be provided by the county supervisors of the Farmers Home Administration to the extent needed.

Loans made to applicants who plan substantial adjustments in their operations may include funds, when necessary, for the purchase of additional land needed to provide an economic family-type unit. Real estate loan repayments may be scheduled over periods, usually not to exceed 20 years.

Federal Crop Insurance Program

Over the years many farmers have availed themselves of crop insurance for wheat. A study of long-time yields, when put on an actuarial basis, results in a rather high premium rate. Even this rate has made crop insurance advantageous for farmers over a period of extreme drouth years. Nevertheless, insurance has encouraged some misuse of resources, for example: (1) farmers were required to seed regardless of soil moisture conditions. When winter wheat is seeded in dry soil with very limited subsoil moisture, chances for a reasonable harvest are extremely limited. But seeding operations further loosen the dry soil and increase the hazard of

wind erosion during the fall and winter season. (2) Approval date of abandonment to qualify for insurance payment was set so late that no other crop could be seeded for the purpose of erosion control. This frequently results in farmers summer-fallowing the land for an extra season, thus increasing the hazard of soil blowing.

Bureau of Reclamation

A federal agency of the Department of the Interior, the Bureau of Reclamation is directly concerned with the development and use of water resources. The activities of this agency are directly related to agriculture through water conservancy districts organized to make full utilization of developed water for agricultural purposes.

Water conservancy districts provide the mechanism by which groups can contract with the government and by which repayment of the cost of development projects may be accomplished.

Power made available through reclamation projects, and particularly that provided to the Rural Electrification Association, is a very real benefit to agriculture in addition to the water for irrigation of crop land.

The Bureau is also the federal agency involved in small-scale land and water resource developments.

...Small Reclamation Projects Act of 1957 (Public Law 948) was enacted for the purpose of encouraging state and local participation in small-scale land and water resource developments.

The law provides for federal loans and grants for the development, rehabilitation and betterment of irrigation projects. This may include flood control, commercial power, municipal and industrial water supply, and recreational programs.

Interest must be paid on loans for irrigation of lands of which no ownership is larger than 160 acres. Users of electric power and users of municipal and industrial water must pay interest on costs allocated for these purposes.

The cost of flood control and fish and wildlife management are borne entirely by the federal government in the form of a grant.

A state, conservancy district, irrigation district, water users association or any public entity qualified to contract with the United States under federal reclamation laws is qualified to apply for loans and grants.

A small project is defined as one in which the cost will not exceed $5,000,000 or, if the sponsoring organization is able to obtain the balance from other sources, the total estimated cost may be as much as $10,000,000.

The sponsor must contribute, as a minimum, all required land rights-of-way and water rights up to 25 percent. The sponsor must also pay all costs incurred in obtaining the loan.

The law requires that any proposal for a project must set forth the plan in detail comparable to the authorization reports prepared for regular projects by the Bureau of Reclamation. The proposal must be an engineering and economic report in sufficient detail to determine the following:

1. Soundness of the plan from an engineering viewpoint.
2. That the estimated cost is adequate to construct the proposed project.
3. That sufficient revenue will accrue to the sponsor to

repay the loan within the repayment period and provide funds to pay for operation and maintenance costs.

4. That the costs allocated to flood control and fish and wildlife facilities are justified expenditures.

The proposal must be submitted to the governor of the state in which the project is located and to the Secretary of the Interior. Both the governor and the secretary must make a finding that the project is feasible. The proposal must be accompanied with a payment of $1,000 to defray the cost of processing the proposal. The full cost of the government's activities in processing the loan is borne by the sponsor and repaid as part of the loan.

The sponsor is responsible for the preparation of the proposal. Personnel from the Bureau of Reclamation are available for advice and consultation but do not undertake technical studies except when it is impractical to obtain such services from other sources. Any such studies undertaken by the bureau must be paid for in advance

Upon approval of the loan application and consummation of the repayment contract, funds can be made available for pre-construction work, including the preparation of designs and specifications. Funds for construction can be made available upon approval of the designs and specifications. During construction, the Bureau of Reclamation makes inspections to assure that the work is being carried out in accordance with the designs and specifications.

Bureau of Land Management

The Bureau of Land Management regulates use of grazing on federally owned lands not in national forests. Grazing use is by

permits inside grazing districts and by lease outside of them. Permits and leases are for ten-year periods. Grazing is authorized to the extent of range grazing capacity. During past years, various adjustments in permitted use have been necessary to reach proper grazing capacity.

Grazing district advisory boards have cooperated with the BLM in improving range management and use. Definite efforts are made to improve the range by adding range improvements, revegetation, erosion control, weed control, and similar actions. Twenty-five percent of collected grazing fees are returned to grazing districts to be used for all types of needed range improvement work.

Forest Service

The Forest Service controls land use within national forests. National forest resources are administered on a multiple-use basis. The guiding policy is to manage these resources so they are used for the greatest good by the greatest number of people over the longest possible period of time.

Grazing permits are regulated under a ten-year lease system. Preference is given to ranch owners whose property borders or is near national forest lands and who need national forest range to round out their operations. Limits are established to prevent any one individual or company from using an unfair share of national forest grazing lands. The permits can be transferred with the inheritance or sale of livestock or ranch property. A grazing permit establishes no right to continued use but is effective so long as the applicant is qualified, the forage is available, and

the area is not needed for what is deemed a higher use.

Construction and maintenance of range improvements on national forest land is usually a cooperative endeavor between the forest service and permittee. There is no set formula for this cooperation.

Because of the variation in topography and types of forage, uniform grazing is extremely difficult to obtain on national forest lands. Consequently a great many range improvements are needed, especially fences. Neither the Forest Service nor grazing permittees have been able to finance more than a small percentage of the needed improvements.

State Agency Programs Related to Land and Water Use

Education and Research

The Colorado Agricultural Experiment Station and Extension Service, branches of Colorado State University, are the agencies best suited by function and responsibility to perform research and education required in the development of a resource program affecting agriculture.

The Colorado Agricultural Experiment Station conducts research on problems affecting Colorado agriculture. Within the limits of available funds, this branch of Colorado State University stands ready to investigate those problem areas which require study before any effective program of resource use can be initiated.

The Colorado Agricultural Extension Service is organized to carry research results directly to the people of Colorado through trained specialists in subject-matter fields and through county agricultural agents and their staffs. This organization is in a position to carry action programs to the people of the state and to solicit program recommendations and guidance from such lay organizations as the Colorado State Agricultural Planning Committee. Field days and demonstrations are also widely used as educational tools.

Extension Service and Experiment Station publications issued by Colorado State University are an effective and continuing method of providing information to the people of Colorado. The methods available within the state for disseminating mass-media information also provide a basic means for communicating education and research activities of the University.

The Colorado Soil Conservation District Program

The Colorado State Soil Conservation law, originally enacted in 1937 and strengthened in succeeding years, enables interested citizens to organize soil conservation districts.

This act is administered by a nine-man State Soil Conservation Board, whose membership includes farmers representing major watershed areas of the state, the Directors of the State Extension Service and the State Experiment Station, the State Commissioner of Agriculture, and one member appointed by the Secretary of Agriculture who has always been the State Conservationist for the Soil Conservation Service.

Briefly, the act provides that landowners in any area may join together to accomplish those conservation objectives by group action that it is impossible to accomplish individually. Organization of a soil conservation district must be initiated by local people. Before a district is approved, basic requirements must be met, including a majority favorable vote at a referendum of all eligible voters in the proposed district.

Districts are empowered to cooperate with federal, state and local agencies. There are no assessments or dues.

Once organized, a district becomes a legal subdivision of the State of Colorado and also a non-profit corporation under the Colorado corporation laws.

Fulfillment of the conservation program depends upon the conservation work accomplished by individual landowners. Many districts provide equipment to aid in conservation work at a nominal rental. The Soil Conservation Service, discussed in a separate section, provides detailed technical assistance to district cooperators. In

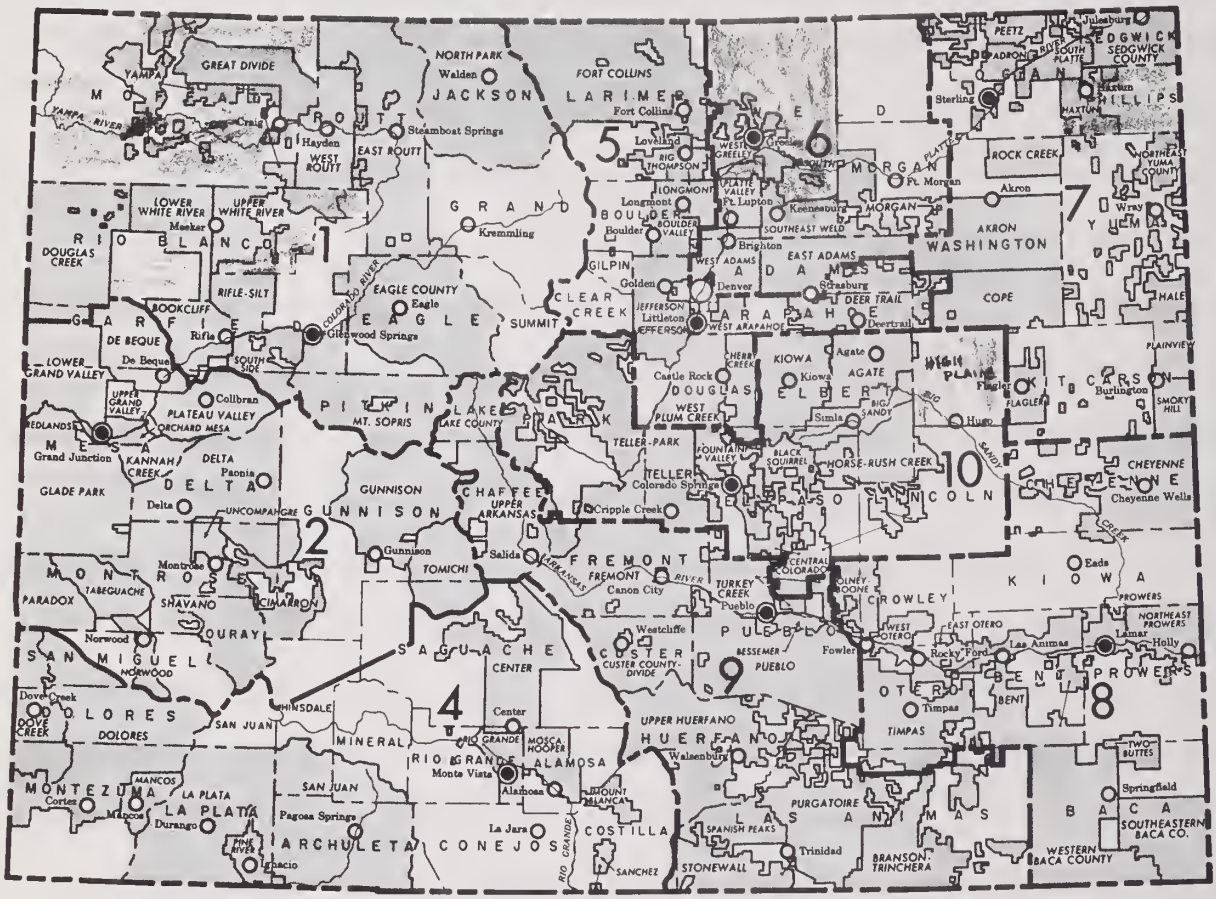
addition, personnel of the Colorado State University Extension Service and Experiment Station work closely with districts and with individual cooperators. County agricultural agents are ex-officio members of district boards of supervisors.

The district program is primarily an action program but it can also function in educating and informing local citizens and in demonstrating results of soil conservation practices.

Although districts are self-administered, they rely to a considerable degree upon agency assistance.

Since 1937, 105 districts have been organized in Colorado. These have been reduced to 98 through consolidation. These 98 contain within their boundaries 85 percent of all farms and ranches and 90 percent of all agricultural lands in the state. Of the 26,918,000 acres of agricultural land lying within soil conservation districts, work is now progressing on 14,667,000 acres. Of the 37,924 farm units within Colorado's soil conservation districts, 16,827 are actively cooperating. Basic conservation plans have been prepared on 11,570 of these participating farm units. As of July 1, 1957, work had been completed on approximately 900 basic plans involving 416,000 acres. The amount of conservation work applied in relation to total need is approximately 12 percent.

The following Colorado Administrative Map of the Soil Conservation Service indicates the land areas involved in soil conservation districts.



LEGEND

- SOIL CONSERVATION DISTRICT
- AREA BOUNDARY
- STATE OFFICE
- AREA AND WORK UNIT OFFICES
- WORK UNIT OFFICE

COLORADO ADMINISTRATIVE MAP

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
DENVER, COLORADO

24 12 0 24 48 72
Scale in Miles

NOTE:
Small scattered additions to districts have been omitted, as the scale of this map is too small to show them. For more detailed information see other appropriate sources.

June 1957

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State Land Board

Nearly all of approximately one million acres of land in the mountain area under the administration of the Colorado State Board of Land Commissioners is utilized for grazing.

This land is grazed under cash lease by individuals who combine its use with the operation and management of their privately owned lands. No lease of such lands for grazing purposes is for a longer period than ten years. Leases may be renewed, however, for a two-, four-, or six-year period at any renewal date. At renewal time, other interested parties have the privilege of bidding for the lease of any lands, but the current lessee is privileged to meet any such bid and thus protect his lease.

In making and renewing leases, the board considers (1) the care and use given the land and the development work done or to be done by the lessee in conserving and promoting the productivity of the land, (2) obtaining optimum long-term revenue for school purposes, and (3) the type, location and contribution to the lessee's unit.

Lease applicants are required to furnish an inventory of their privately owned land resources and use pattern as well as the intended use of the land to be leased. In case of a renewal, the history of use for the past lease period is required.

The board may cancel any lease for misuse of the land or for false statements by the lessee.

Board fieldmen inspect all lands and leases and determine equitable leasing rates under existing local conditions. The 1956 receipts from grazing-land leases in mountain counties averaged $ 0.252 an acre.

The State Board of Land Commissioners presently has no provisions or funds for the improvement of state lands. Any and all improvements must be made and maintained by the lessee.

Many other state agencies such as the Colorado State Forest Service, the State Engineers Office, and the State Water Conservation Board are involved in the use and conservation of agricultural lands and water use on irrigated lands. Most of these agencies, however, are limited to specific areas of interest and are not reviewed in detail in this section of the report.

IRRIGATED AGRICULTURE

Irrigated agriculture plays a vital role in the maintenance of a stable and healthful economy for Colorado. Contribution of irrigated farming to the state's agricultural income is indicated by the following table:

Share of Total Farm Value of Crops Produced on Irrigated Land

5 Year Averages (1951-55)

Crop	Average Total Value of Crop Production	Avg. Value of Production on Irrigated Land	% of Crop Raised on Irr. Land
Corn	$22,063,000	$17,331,000	78
Winter Wheat	69,486,000	2,640,000	4
Spring Wheat	2,648,000	1,542,000	58
Barley	10,392,000	7,397,000	71
Potatoes	20,493,000	20,411,000	99
Oats	4,001,000	2,975,000	74
Beans (Dry)	20,692,000	16,169,000	78
Sugar Beets (Yrs. 1950-54)	22,478,000	22,478,000	(100)*
All Hay	60,076,000	54,068,000	(90)*
Sorghums (Grain)	3,863,000	-----	(00)*
Sorghums (Forage)	5,703,000	-----	(00)*
Com. Vegetables	14,052,000	14,052,000	(100)*
Fruit Crops	7,452,000	7,452,000	(100)*
TOTAL	$263,399,000	$166,515,000	*Estimated %

Approximately 63 percent of the average value of Colorado crops, grown during the 5 years 1951-55, were produced on irrigated land. Feed raised established the base for at least an additional $100,000,000 worth of dairy products and meat in lamb and cattle gains produced from feeding programs.

Tremendous sums have been invested in developing irrigation facilities; the total to 1950 was $163,500,000. There were nine U. S. Bureau of Reclamation projects completed and under construction. The estimated total ultimate cost of these projects is $204,503,081. Thus, the total estimated investment in all irrigation enterprises is now approaching $370 million. Additional multi-million dollar projects are planned.

Careful study and wise decision as to future use of water and irrigated lands is a "must" in total state resource use and development. Understanding the capabilities and limitations of these resources is necessary if Colorado is to capitalize on its resource potential.

Inventory

Total net acreage under irrigation is difficult to determine. It fluctuates with water availability as influenced by precipitation cycles. The most practical guide is the irrigated acreage reported at five-year intervals by the census. These reports show the following irrigated land in farms since 1940:

1940	2,468,000 acres
1945	2,699,000 acres
1950	2,862,000 acres
1954	2,263,000 acres

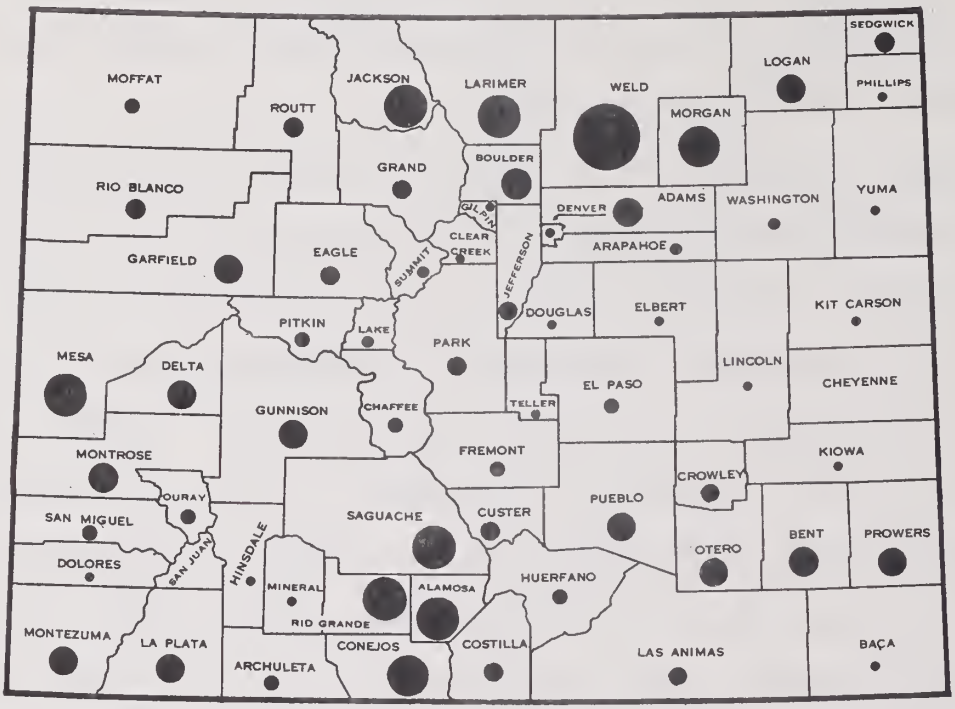
Thus, coincident with low precipitation, the 1954 acreage gives the smallest in the series in spite of a phenomenal growth in pump irrigation. County-by-county acreage for 1950 is shown by the map on the following page.

Origin of water is of extreme importance--both in terms of historic irrigation development and in relation to the future use of Colorado irrigation water. The portion of the state west of the continental divide has 37 percent of the total land area, but 69 percent of the surface water yield is found here. In general, largely because of geographic conditions, western slope lands do not lend themselves to intensive agricultural production as readily as do lands on the eastern slope. Moreover, total irrigable land (particularly on the eastern slope) far exceeds the acreage for which water can ever be available. So intra-state competition for irrigation water by diversion from the western slope poses a difficult problem.

History

Because the principal use of water has been for irrigation, most of the history of its regulation and administration is directly related to this use. This does not mean that all needs must be subservient to irrigation; but it has meant that the major principles of public policy regarding water use have largely developed to serve irrigation. Most of the pattern of development of the appropriations doctrine has been the formalizing of regulations and administration to meet irrigation requirements. The Colorado law provides priority preference in

Colorado: Acres Of Irrigated Land, By Counties, 1949



300,000 - 399,999 Acres	10,000 - 19,999 Acres
100,000 - 199,999 Acres	5,000 - 9,999 Acres
50,000 - 99,999 Acres	Less Than 5,000 Acres
20,000 - 49,999 Acres	

use of water in this order--domestic, irrigation, and industrial. The order further emphasizes the historic precedence of irrigation water.

Development of Water Law

It early became evident that an orderly method must be found to ration stream flow among a rapidly increasing number of claimants. The riparian use theory--the flow of a river must no be diminished in either quantity or quality--was found to be inadequate so a new appropriations doctrine began to evolve. The doctrine has much to commend it. Essential points are:

(1) All unappropriated waters of any natural stream are declared by law to be "the property of the public, and the same is dedicated to the use of the people of the state..."

(2) The right to divert unappropriated waters of any natural stream for beneficial use shall never be denied.

(3) The right to use water is predicated on beneficial use.

(4) The first appropriator in time is first in right.

There may sometimes be temptations to feel that this body of waterlaw and administration is out-dated, that it should be abandoned in favor of a system of centralized authority that would specify how, when, and where water should be best used. But most observers confirm the value of the appropriations doctrine as a logical development consistent with our traditional free-enterprise philosophy-and flexible enough to meet new requirements and conditions imposed by the passage of time.

It is true that the doctrine (as embodied in law, organization, and administrative structure) has both strengths and weaknesses. Some exposition of the weaknesses is pertinent to finding ways and means of incorporating desirable flexibility into water law and practice.

Beneficial Use

It will be recalled that one tenet of the appropriations doctrine is that the right to use water is predicated on beneficial use, a term so far subject to extremely liberal interpretation. No specific preference is recognized between greater and lesser economic use. Unfortunately, perhaps, priority of that use-right by time of appropriation has been the practical determinant of use-right. In the past, this has posed a less serious problem than can be foreseen for the future as inevitable multi-purpose and conflicting use-purpose demands come more sharply into focus.

The natural operations of supply and demand economics has been somewhat effective in permitting greater economic use to assert its claim for water over uses less economic. Water rights can be purchased for use in a lower category of legal preference (industry can purchase agricultural rights). Unfortunately, however, cumbersome judicial and administrative procedures of water administration often operate to restrict the effectiveness otherwise associated with supply-demand economics. Suggested changes are discussed in some detail starting on page II-22.

Another means of re-allocation to more economic use exists. Rights may be condemned, with compensation, for a higher preference (municipalities could condemn to obtain irrigation or industrial rights).

While some inertia to prevent haphazard or capricious reallocation of water is desirable, the aim should be to facilitate the appropriations doctrine's workings rather than to alter its basic framework. The alternative would be to design a new basic doctrine attempting to assign economic values to a multitude of uses and users as a basis of water distribution. It seems obvious that such an attempt would break down from sheer weight, especially if the democratic principle of judicial determination were respected.

Future Problems

It takes no prophet to state the prime reason for diligent consideration of water-use problems. Dramatic intensification of water-use demand is inevitable. Domestic use per person increases yearly; Colorado population will grow some 60 percent by 1975; industrial development is mushrooming; agriculture seeks supplemental water for existing acreage and also to capitalize on undeveloped potentials for new acreage. For whatever purpose, future development costs will be high. Once decisions are made, they become tangled in the previously mentioned cumbersome judicial and administrative web. Then opportunity to achieve optimum potential use is at least partially lost. The time for wisdom and considered program in improving our machinery for dealing with water is now!

Use Conflicts

Fortunately, although many complicated water-use conflicts do exist, there is much room for development that will satisfy more than one group of users. Not all water used for domestic

or industrial purposes is thereby lost to agriculture; not all irrigation water is lost to other uses.

City and industrial growth poses a threat to irrigated agriculture in two ways. Each new family requires about one additional acre-foot of water annually. As cities grow, so does industry; and industry too is a heavy water user. As already recognized, in neither case is all the water used consumed and lost to agricultural use, but perhaps 50 percent is lost and other deleterious effects may occur: (1) The process of acquisition may change the location of availability drastically; (2) return flow may be polluted and unfit for use in irrigation.

There are also cases of direct conflict of interest in developing unallocated water. Consider Denver's program of water development as an example.

According to a statement in the Hill, Leeds, Hill, Jewett report (1953) on water supplies in the Colorado River in Colorado, there would be enough water for the proposed Blue River Project to supply supplemental irrigation water or for Denver's proposed transmountain diversions, but not for both. Thus, with Denver's perfected plans in 1956 for a diversion of 177,000 acre-feet of water, it appears that the Blue River project for irrigation purposes is not feasible. Further, in order to obtain the water, certain concessions to Western Slope interests were necessary, limiting Denver's diversions to municipal use only.

In the past and at the present, the use of ground-water by cities in the plains area has not resulted in any obvious conflict with the use of such water in agriculture. Such conflict is quite

possible, however, in much the same manner that agricultural use of that water is in conflict with stream flow. Such cities as Sterling, Fort Morgan, Fort Lupton, Brighton, Thornton, and Denver in the South Platte drainage may be drawing upon ground water that could relate to stream flow and thus infringe on prior appropriation rights. Colorado Springs and other cities in the Arkansas River drainage pose the same type of problem. Lack of fundamental ground water data prevents accurate evaluation of the problem.

A broader area of conflict (and one most unfortunate in relation to its possible effect in blocking action to put unallocated water to beneficial use) is the lack of unity between east and west slopes on distribution of unallocated waters from the Colorado River basin. Western Slope residents understandably are determined to preserve for their use not only water to meet present needs but also to provide for reasonable future developments. No one yet has a clear picture as to amount of water required or as to date that it will be needed. Wants of Eastern Slope users are more immediate and perhaps more clear cut. Therefore East Slope users are impatient to initiate action now. So east-west negotiations have tended to be charged with emotion not conducive to rational agreement. This state of affairs is worsened by lack of adequate factual data and investigations that might point the way toward agreement. The principle of compensatory storage of peak run-off for later use should help to resolve the conflict as soon as tempers cool and an objective

look at needs of the respective areas can be made.

Meanwhile, increased availability of water for agricultural acreage (and for other purposes) will probably await a meeting of minds between the slopes. It will also be conditioned by the amounts of public subsidy made available through Bureau of Reclamation programming. There is some threat that agreement too long postponed will result in loss of water to other states ready to put it to beneficial use. Decisions finally made will be a major factor in determining specific areas where undeveloped water will be used. Since domestic uses have preference, domestic demand is soaring, and domestic users can better meet the inevitably high costs, a considerable portion of the increase may be absorbed for this purpose.

Recommendation: The Department of Natural Resources should do all within its power to resolve the East-West Slope controversy over water use and to plan for use of all unallocated water within the state. The following specific actions must be taken to accomplish this objective:

1. Obtain complete and accurate inventories of the total water resources of Colorado with particular reference to unallocated water.
2. Determine the pattern of present water use.
3. Determine areas of greatest immediate need and areas of potential need.
4. Evaluate available water resources compared to future needs and then apply a sound, long-range program for development of unallocated water based upon use that will prove most feasible, most economical, and provide the

greatest benefit to the most people over a long period of time. The department should occupy a position of leadership in bringing East and West Slope interests into common agreement at the earliest possible date.

Federal-State Cooperation

Major questions and policies related to the federal water program are vital matters in which Colorado must interest herself.

The day of cheap and easily constructed water projects is largely in the past. The works and improvements of the present time require large expenditures of money. They must be built under repayment terms and conditions which will not impose an undue burden on their beneficiaries. An era has been reached when all river basin water development in its major aspects must be integrated. In short, the time has come to "cut the final pattern" for the best use of this vital resource.

Recommendation: In view of this situation, it is necessary for the state to intensify close cooperation with (1) federal agencies which participate in water development; (2) local affected groups and interests within the state; and (3) with other affected states within particular river basins. The recently enacted Public Law 948, Small Reclamation Projects Act, is worthy of study as a development tool calling for state and local participation. See page I-44.

Internal Conflict

Considerable conflict in water use exists within irrigated agriculture itself. These conflicts will probably become more pronounced with the passage of time.

Since Colorado farmers possess much more irrigable land than

water available for irrigating purposes, increased competitive demand for the limited supply suggests some logic in shifting developed water to land best suited to use it. Such allocation is not automatic under our water doctrine. Better water rights are not necessarily associated with best adapted land. As suggested heretofore, right of purchase tends toward economic use but by no means does it result in optimum use from the standpoint presented here.

For those who might be tempted to move too rapidly, this aspect of water use must be considered: Wasteful practices or use on land not best suited may be much less wasteful than appears at first glance. For example, in many localities it is often necessary to use quite muddy direct-flow water; this may necessitate irrigation runs of long duration with a considerable portion of the applied water leaving the farm. In most instances, this surface "waste water" is picked up on a neighboring farm and reused. The overall efficiency of water in the Arkansas and South Platte valleys is generally of an exemplary degree of efficiency in terms of total acres to which it is applied.

Ground Water Policy as Related to Irrigation

A final water-use problem (largely within agriculture) is the complicated and very controversial question of ground water. As technological improvements made pumping feasible and this means of developing water began to mushroom, another weakness developed in the application of the appropriations doctrine in Colorado. The framers of the constitution, perhaps inadvertently, failed to mention underground or ground water as a part of the water supply.

All water--whether ground, surface, or atmospheric water--is a part of the hydrologic cycle. There is actually no exact and well-defined line of separation between these three common classifications of water, as evident and distinct as they may seem to the average observer. This is especially true with respect to ground water and surface water.

All ground water (except geological water or water held isolated or captive by geological structures) is moving toward some body of surface water. Geological or captive water is of little or no importance.

Under-flow waters of stream beds may be part of the surface-flow for a comparatively short distance or period of time, disappearing again into the river bed a little farther along. It is equally difficult to find a line of separation between the under-flow of a surface stream and ground waters pressing in from a slightly higher elevation. Still there are those who insist these are separate bodies of water and that a different theory of appropriation can be applied to them. Lack of clarity and of knowledge seriously handicap a reasonable approach to administration.

Previous to the passage of ground-water legislation by the 41st General Assembly in 1957, Colorado was virtually without a public policy on the use of ground water for irrigation. The ground-water act of 1953 required only the reporting of new wells drilled and the filing of logs by well-drillers. Part of the act permitted the formation of ground-water districts but was so loosely drawn as to be inoperative.

Since there have been no legislative statutes governing the use of ground water, when such cases came before the courts decisions were based upon statutes and precedent governing stream-flow use. Both the rule of priority of appropriation and the American rule of reasonable use have been employed. One tenet developed and adhered to by the Supreme Court has been that ground-water is presumed to be tributary to stream flow. Those who claim differently must clearly and definitely show that it is not tributary. In other words, the burden of proof lies with the ground water user.

Since ground water is considered tributary, users are placed in legal jeopardy under conditions governing the use of surface-waters. Pumping from wells for irrigation did not assume much importance before 1920. But the water in all Eastern Slope streams was fully or over-appropriated before this time, in fact, before the turn of the century. Ground-water appropriations are, therefore, all junior to surface-water appropriations. The removal of ground water for irrigation then is an operation actually outside the law and no rights thereto could be perfected.

Interference by Pumping

Where ground waters occur in the superficial sediments tributary to surface streams, there is a profound and correlated relationship between pumpage and stream flow. In this situation, surface water rights can and are being converted to pumpage rights. If the pumped water is in lieu of a surface right already owned by the pumper, no inequity occurs. But this is not the normal case and

such pumpage can only be in conflict with surface rights. This is not to deny the many possible advantages of pumpage. This dilemma is widely recognized as one of Colorado's most serious irrigation water-use problems. Ground water tributary to streams is an important resource which needs to be utilized. Existing surface rights are a key factor in agricultural production and must be reasonably protected.

Recommendation: There is considerable misconception about the occurrence and movement of ground water. Improved public understanding--especially about some of the more common, gross misunderstandings--would help a great deal to prepare the way for effective legislation. Research and investigation leading to improved inventory and understanding of the resource and its limitations is badly needed. Both of these steps are essential elements of public policy.

Past and Future Consideration

In the past, the development of ground water in Colorado progressed untouched by law on a laissez faire basis. A valuable natural resource was put to beneficial use to produce wealth. In large part, it was used as a supplemental supply to stream flow. But consequences of excessive withdrawals were not adequately considered. No laws were in effect to prevent complete exploitation of the resource.

The ground-water act of 1957 was the subject of long and acrimonious debate before final passage. The bill as originally presented to the senate was greatly changed, especially as to the parts based on priority of appropriation. As passed, the act is to

be administered by the state engineer and an eight-man commission. Its functioning may be almost solely in regions remote from stream flow in "tentatively critical ground-water districts." The commission may take the initiative in designating such districts, or such a district can be formed by petition from a substantial number of users within the district. All existing wells, other than those used for domestic purposes, must be registered within three years. Permits are required from the state engineer for new wells. He may refuse to grant such a permit in a critical district. A district advisory board of five members will be elected in each "tentatively critical ground-water district." This board has advisory powers mainly but by unanimous vote it can terminate the designation after one year of operation. All well drillers must be licensed and bonded.

As may be seen from the foregoing, the act will function along the lines of "local option." In some cases, it probably will not provide effective state or public control or conservation. For stricter control, the power of the advisory boards would have to be reduced. It should also be pointed out that no real attempt has been made to compromise the conflict between surface and ground-water users. At present, it is impossible to predict how well the new law will function. As with other important and controversial laws, it is quite certain that this act will be changed to meet conditions pointed up by experience.

This situation already suggests a number of questions for which answers are needed:

(1) Should two full or near full water rights be permitted for any given tract of land--one from a canal and another from wells drawing water which is actually or essentially the same supply? Under the Colorado theory of appropriations, a right to divert water to beneficial use applies not to the total quantity used during a season but to the maximum flow which may be taken at any given time. Several court cases have considered "the duty of water," but there has been no particular effort made to reach a basic decision for any water district. Of course, farmers do not normally run up electric bills for pumping when their ditch right is available. Surface water rights are effective only when water is available in the river. The use of ground water has been and still is essentially outside Colorado law.

(2) What is the net effect on stream flow of well pumping from aquifers carrying, or attached to, under-flow of a stream? Guesses have been made but no adequate study has been conducted. With very few exceptions, pumped water is used near the well and half or more of the pumped water is believed to return to the mother aquifer.

(3) Is the present system or lack of system the best method of obtaining the greatest possible benefit of the storage waters underlying valleys like the South Platte, Arkansas, Rio Grande, and other Colorado drainage systems?

(4) If the present practice is the best that can be devised, how can down-stream sections in Colorado--on the South Platte and the Arkansas, for example--be assured of their fair share of both the direct flow and under-flow storage? Who should pay for the

planning and facilities to deliver water to the lower valleys during water shortages?

(5) What should the policy be toward the use of this stored ground water? Should one or two generations be permitted to exploit it or should its use be spread through several generations? Will the rate of replenishment be sufficient to provide domestic and livestock needs?

These are long-range policy problems unanswered in those areas where the ground-water aquifers are either not connected with any surface stream in Colorado or are so removed by distance or cut off by geologic structures that they may be regarded as distinctly separated. These areas are principally in the eastern plains area of the state. Most of the ground water found there has been accumulated over millenniums of time and should be considered as storage. The only source of replenishment is from local precipitation.

Colorado, in this and some succeeding generations, is entitled to the economic benefits this water will produce. However, after the stored water is used, the area will have no supply but the annual replenishment. The rate of replenishment, according to the United States Geological Survey, is about .25 of an inch in the hardlands to .9 of an inch in the sandy soil areas. At these rates, it would require some 4,800 acres of hardland watershed or about 1,300 acres on the sandy lands to provide an annual supply of 30-acre inches per acre for every 40 acres irrigated.

Unfortunately, it is already too late in Colorado to avoid considerable emotion based on vested interest that is part and

parcel of already-developed pumpage. This doesn't relieve the state from deciding whether it prefers a short-lived (largely unregulated) development of ground water or a conservative long-time use. The former amounts to a mining operation, the latter provides a basis for a more stable and enduring economy. The lift-depth history recorded on the following page illustrates the problem. Only by regulative legislation can unlimited use be prevented and an orderly program of development be assured. Care should be exercised that the legitimate development of ground-water should not be hindered by unwise legislation and that the ex-post-facto aspects of legislation recognize an obligation to compensate damages suffered by those who may have developed water prior to regulation.

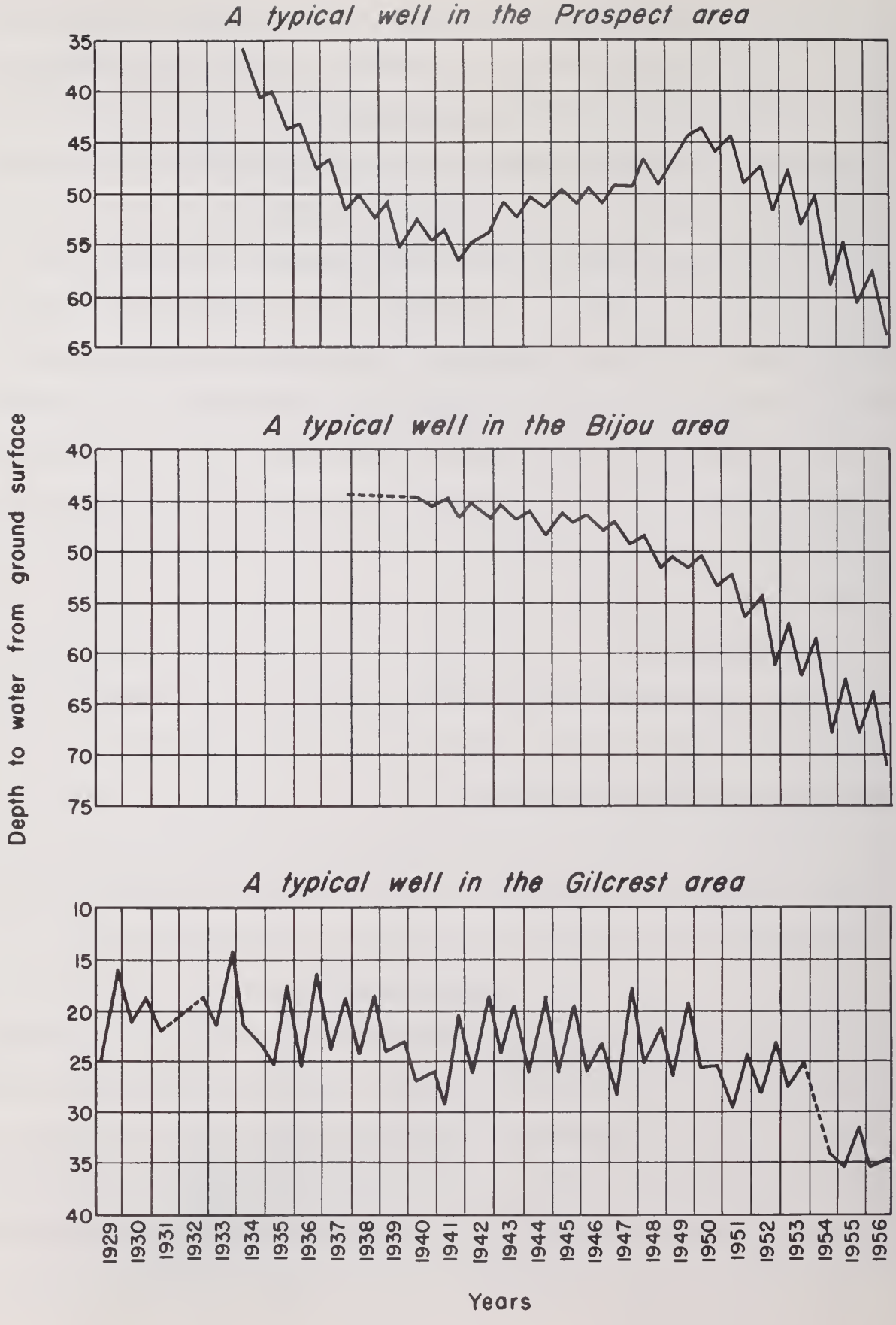
Recommendation: It is imperative that intensive research, education, and sound policy implementation be undertaken. This should be a high priority item in the policy program.

Non-Water Irrigation Problems

Non-water economic changes that pose problems for irrigated agriculture are (1) pre-emption of irrigated land for city and suburban housing and (2) super-highway construction.

Urban Growth

In the former case, an estimated 16,000 acres of irrigated land have been taken over by urban growth in the past ten years. Apart from the loss in food production base, it is worthy of note that--although additional water may be released because of the change--no new lands are substituted for the lost acreage. By and large,


A typical well in the Prospect area
35
40
45
50
55
60
65
A typical well in the Bijou area
40
45
50
55
60
65
70
75
Depth to water from ground surface
A typical well in the Gilcrest area
10
15
20
25
30
35
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1929
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1931
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1956
Years

the released water is used to enhance existing water rights. But it seems clear that no practical policy can or will over-ride the strength of economic demand for expansion acreage. Therefore additional attrition on land presently irrigated is to be expected

Recommendation: Concentrated attention should be directed toward improved zoning laws--in this case to provide due recognition to needs of farmers in transition areas as well as those of city dwellers, laws that will enhance orderly transition.

Super-Highway Construction

The other principal non-water "intruder" and one of considerably greater total threat to agricultural production and welfare grows out of super-highway construction. This has two serious aspects: (1) It can and often does cut through a unit in a way that poses serious management problems. Fields are cut into non-economic shapes and sizes; access to part of the farm is made difficult; the water management pattern is disturbed or destroyed; the lost acreage may be the difference between an economic size of unit and one that is too small.

The importance of routing highways in accordance with best engineering requirements should not be minimized. But most irrigated valleys are relatively narrow. The primary purpose of super highways is cross-country travel; an awareness of opportunity to route through non-irrigated lands (and therefore with much less disturbance to agricultural organization and values) might achieve considerable public good.

Recommendation: With the advent of the federal super-highway program already underway, no time is to be lost. Immediate consul-

tation with state and federal highway authorities is advised to explore practical ways to reduce destruction of irrigated land and farm units.

Administration of Irrigation Water

Responsibility for administering the use of surface water is vested by the statute in the state engineer. Rights are obtained by users in certain prescribed ways. Briefly, the procedure involves filing a claim and establishing beneficial use. The actual right and priority of right is established by a district court decree after an adjudication. The state engineer is bound to deliver the water of the natural streams to the diversion points in accordance with such decrees. At this point, conveyance and distribution becomes the responsibility of the user. The state engineer exercises his responsibility through division engineers, each responsible for one of the state's major drainage basins. The seven divisions are sub-divided into a total of 70 water districts. A water commissioner administers the natural streams of each district. These commissioner exercise police power over the districts and must meet water demands in order of priority within the available streamflow.

Individuals may divert waters directly from the streams or groups of individuals may form organizations to divert their common water rights. Common forms of organizations for this purpose are mutual stock companies, irrigation districts, and (formerly) carrier companies. Mutual stock companies are owned by the farmers who retain stock in the company. These are organized under special charter by the state and are self-governed. They are organized as non-profit corporations under Colorado statutes and thus are tax exempt.

Mutual stock companies own the diversion and canal works of the system. They do not own the water rights as such. They obtain revenue by assessment of the stockholders who receive irrigation water in proportion to their stock.

Irrigation districts are organized under laws enacted in 1905 and subsequent thereto. They are a form of benefit districts. They may assess certain costs as a tax directly against the land benefitted. Usually, capital costs are paid in this way whereas operating costs are ordinarily assessed on the basis of water delivered.

Carrier companies, as such, are largely obsolete. These were private companies designed only to divert and distribute water to non-member irrigators for profit. They are classed as a public utility. If a mutual company transmits water, however, for non-stockholder owners, it becomes a carrier. It is operating as a utility and so is no longer tax exempt. Most companies are reluctant to transmit "foreign" water for this reason.

Under legislative act of May 13, 1937, formation of conservancy districts was authorized. These districts have the additional power to assess general taxes against <u>all</u> property within their boundaries. Financing is intimately related to the type of organization. The conservancy district, since it may impose general taxation, has the highest degree of financial flexibility and responsibility. The irrigation district, which can encumber land with a benefit lien, is somewhat less responsible; in turn, the district is more responsible than the mutual company which can place a lien only on its corporate property.

Districts may also be organized for the purpose of draining irrigated land under the Internal Improvement Districts Law of 1923. These districts have powers comparable to those of irrigation districts.

Administration of interstate streams may involve federal court action. In this event, the state engineer is required to allocate the water as prescribed by the resulting court order. More commonly, Colorado has joined its neighboring states in writing interstate compacts relating to the use of water in specific interstate streams. The interested states and the federal government are parties to such compacts which, when ratified, become the basis for allocation of water between states. Compacts are negotiated by specially authorized and appointed commissions representing the interested states and a representative of the United States. The state engineers of the respective states administer some compacts while others are administered by a commission provided for in the compact. Colorado's representatives to such commissions are appointed by the governor.

While the basic public surface water philosophy of Colorado may be judged eminently sound, there is much that could be accomplished to improve judicial and administrative procedure. It should be recognized that the overall problem has many facets, any single one of which is complicated and has a great many ramifications.

Recommendations: (The following suggestions are intended to raise questions where there appears to be a favorable possibility of improving conditions. In no case is a change in the present

procedure advocated without first conducting painstaking and thorough research.)

(1) Codification of Water Law--The state engineer must become familiar with and comply with a vast and somewhat disconnected body of statutory law. If the water law could be simplified and codified, his job would be easier and there would be less opportunity for conflicting situations to arise.

(2) Change of Diversion Point--Diverters may change their points of diversion if the change is approved by a court after a public hearing. Since a change of diversion may adversely affect the other diverters by reducing the availability of water in a stream, they have the privilege of protesting such a change. The person seeking the change must prove that no injury will result. A junior appropriator is entitled to have the conditions which existed at the time of his appropriation continued and maintained. There are questions of return flows, the period of time appropriation is used each year, and many others that can be raised to make the change difficult or impossible. So the common tendency is to protect the status quo diligently, even through injuries are fancied or minor.

"Freezing" points of diversion is an important factor which often prevents the free operation of supply and demand for water, thus obstructing better economic use. There should be some safeguard to other interested parties, of course. On the other hand, pure legalistic obstructiveness which reacts against the best use of a resource as scarce and important as water

must be eliminated. A procedure is needed which can exercise reasonable protection but which will insure that progress is not obstructed by fancied, trivial, or unreasonable factors.

(3) Storage-- Allocation of water to storage sometimes seems more arbitrary than rational in so far as public interest is concerned. The uniform April 1 cut-off date and the priority of direct-flow over storage rights often results in water being poured onto lands which may not need it.

Under the Colorado appropriative system, each canal company and each individual user often feels duty bound to divert all the water to which it or he may at the moment be entitled. The water may not be needed at the time but fear of not being able to obtain it when needed forces its diversion and deprives another appropriator who may be in much greater need. The basic cause lies in the unplanned and uncoordinated system of canals which has developed under undirected private initiative.

Water laws in Colorado are such that water decreed under a direct flow decree cannot be stored in a reservoir for subsequent use. This is on the principle that the water must be distributed in strict order of priority and the right of direct flow user extends only to the amount of water he can use beneficially at the moment. Modification in recent years permits limited storage in overnight ponds so more efficient use can be made of the water in daytime. There is need for the expansion of this practice where feasible

Carrier company tax status operates as a hindrance to more efficient storage and distribution. Since there appears to be a definite possibility that distribution of water might be improved if tax liability were removed, a study of the possible benefits from necessary change in law is suggested.

In the public interest, a much more economic use would be to store such water in a reservoir. The problem is related to the definition of beneficial use which, if more strict, would help to avoid such wastefulness.

Perhaps the senior direct-flow appropriator could be provided with some material incentive to give up his excess water from direct-flow rights to storage wherever suitable storage can be provided.

Admittedly, improvement of the situation would be difficult and would probably mean substituting some police power and voluntary decision in place of the present procedure. In any case, the conflict of direct surface use against storage ought to be thoroughly studied. There appears to be considerable opportunity to effect public water economy here.

(4) Exchange--Under Colorado procedure, individual users may satisfy an earlier decree by providing the water for the decree from some source other than the natural stream of the diversion point. For instance, a junior appropriator may divert a senior flow-right upstream, replacing such right--in a manner satisfactory to the owner--from storage water owned by the junior. This allows the junior appropriator to provide water for lands which cannot be commanded by his

reservoir. On some streams, exchanges become quite complicated. Exchanges do provide, however, helpful means to allow supply and demand to operate and thus are a force for higher economic use. The whole exchange system seems highly artificial, however, and it is possible that a simplified, consolidated water-right system on a single stream could be devised, a system which would deliver essentially the same water to all concerned as is now received.

Distribution of Water by Canals

There is much improvement to be desired in the distribution and rationing of water to shareholders by ditch and canal companies. No one distribution system is adaptable in all areas under the varying conditions of stream flow, average quantities of water available, different storage facilities, crops produced, and other conditions affecting supply and needs.

Some canal systems have been able to meet the needs of their shareholders quite effectively. As a general observation, the larger systems have done a better job than the small-ditch groups. The most obvious reason appears to be overall cost per share. However, even under the better managed systems, there is considerable reluctance on the part of many water users to adopt new methods, particularly if the new system costs money.

Common methods of distribution may be grouped into these general types:

(1) The constant availability system, used on a few ditches with ample senior decrees and diversions, forms a reasonably constant direct-flow supply sufficient to meet most or all normal demands. Farm headgates are never locked.

(2) The constant distribution of a water flow. When divided among all users, water is generally insufficient for economic use by individual farms except during springtime periods of high water availability. This system and problem is most common in western Colorado areas where farm tracts are small.

(3) Some canals use sectional rotation systems after their spring peak supplies are past. This system is based on an assumption that the farm operator is entitled to irrigate all his crops every "rotation." The result is that any given farm may receive several widely separated but large runs of water, interspersed with rather long dry spells. It usually happens that one or more sections on a long canal will receive one run less in a season than the other sections. Missing this last run is often a critical loss

There is a variation of the sectional rotation system that is good from the standpoint of equitable distribution of a barely adequate summer and fall water supply. Under this system, an attempt is made to meet necessary minimum requirements--every week or ten days, for example. The volume of water delivered is generally sufficient for reasonably efficient irrigation, but the duration of the run sometimes permits irrigation of only the most important crops or areas.

Another variation is for all farm gates to be set at a point consistent with the quantity of water in the main ditch. There are a large number of operations that may be classed in the rotation-type group, including many canals with fair to good storage supplies that supplement some direct-flow rights.

(4) There is the fortunate group of canals that have sufficient storage to operate on the "demand system." Water is supplied on demand of the user. There are only a few of these.

(5) There are some systems which have limited supplies of storage water and make a season's allotment to each farm each spring. This type of operation requires careful measuring; with good timing, quite efficient distribution of available water can result.

There are almost as many variations of all described types of ditch operations as there are canal and ditch companies. Many of the smaller operations are quite haphazard and can hardly be said to have a system. Each farm operator seems to take whatever water he needs whenever there is water available at his farm headgates. In this case, the upper end of such irrigation systems may prosper every year while the lower end suffers most years.

The major points of concern are these:

(a) Many canal and ditch systems need both physical and managerial improvements.

(b) There is need for more water measuring or metering devices along canals and better operation of those now in use.

(c) More electronic recording devices are needed for more accurate operations. Such devices properly located would same time and car mileage expense.

(d) The state engineer's office needs better financing to permit it to employ and hold better qualified people.

In many water districts, county commissioners, irrigation districts, and canal companies are paying all or part of the water commissioners' salaries and expenses. Water administration is a state

function. Canal companies should not be permitted through the power of the purse to influence those who regulate their water diversions.

Transfer

Legal obstacles seriously hinder movement of water from one ditch system to another to effect an improvement in total distribution efficiency.

Recommendation: Possibility of facilitating this type of transfer should be studied.

In-Transit Losses

In-transit losses of water seriously reduce the effective amounts available for use in crop production. This loss occurs from the point of diversion and includes great evaporative loss, particularly from shallow reservoirs.

To illustrate the problem, serious in-transit losses have been experienced in delivering Colorage-Big Thompson Project water to allottees in Morgan County. Individual allottees have often become discouraged and released their rights to users on tributary streams west of Greeley.

Runs made to the Bijou and Riverside Canals during the summer of 1954 suffered especially serious losses. The most serious loss was a little more than 60 percent from a run made July 6 to 12. A total of 2,273 acre-feet was measured out at the mouth of the Big Thompson Canyon. The canals received a net of 900 acre-feet. Other runs also suffered but not quite so heavily. The intakes of these canals are some 30 miles down the South Platte from the mouth of the Big Thompson.

No doubt the years of drought have been an important factor in these difficulties as evaporation from stream and river bed surfaces increased greatly.

Recommendation: Studies should be conducted to find means to reduce evaporative and other kinds of in-transit water loss.

Companies and Districts

Much of the responsibility for the best economic use of water in Colorado must fall squarely on the individual irrigation companies and districts. From the viewpoint of improved economy in the use of water, there is much to be desired. While effective as pioneer agencies, cumulative problems and present conditions render many ill-suited to handle present-day problems. Among the principal shortcomings are the following:

1. Facilities are duplicated. Many small, duplicate canals could be replaced with single ditches much more efficiently designed, constructed, managed, and operated. By consolidating, the owners could afford to have decent diversion works and canal structures instead of obsolete, inefficient, wasteful structures now extant in Colorado.

2. Management is poor. Although few farmer-dominated irrigation ditch boards will admit it, proper management of an irrigation distribution system is a technical job requiring some basic education in hydraulics and engineering plus specialized experience in irrigation system operations. Many small companies cannot afford good management; others don't want to.

3. Operational wastes cost both money and water. Under many

systems, too much water is diverted and seeps from the canal or leaks out through leaky headgates to waterlog land, breed mosquitoes, and grow weeds. Far too much money is spent on "half-baked" structures built without engineering advice. If the money spent on structures designed and built by amateurs had been put into good structures, a number of presently poor distribution systems in Colorado would be good ones.

4. Delivery methods are not adapted to needs but are often based on tradition. Continuous stream delivery is hard to justify. Consolidation of continuous rights and simple rotation could do much to improve efficiency in many parts of Colorado. Where storage is available, demand delivery may be possible in part. But on many systems, storage is sadly lacking. Sometimes this is very difficult to provide. Too often the reason it can't be done is because a number of small systems are unable to resolve petty differences.

5. Water measurement is poor. There is widespread misconception about how to measure water. Strangely, most amateur water measurers are sure that their methods are correct although they are not in accord with known hydraulic laws. Perhaps the most important single thing that could be done to improve water-use efficiency would be equitable and proper measurement of water to every user at his headgate. On many systems, the farmers on the upper part of the ditch get most of the water while those on the lower end get little or none. This is unlawful and unfair. Rigorous measurement could prevent this. At least part of the cost of water to the farmer

ought to be based on the volume of water delivered. There is no more effective way to promote efficiency of use. Complete and accurate water measurement at each farmer's headgate is the primary step which should be taken to improve water-use efficiency.

6. Weeds are not controlled. Water-borne weeds cost Colorado farmers hundreds of thousands of dollars every year. Weeds along irrigation canals and reservoirs should be controlled.

7. Small companies are poorly equipped. Efficient and economic maintenance of irrigation distribution facilities in this mechanized age requires considerable investment in specialized equipment and in skilled labor. Most Colorado companies are not large enough to afford the necessary equipment.

8. Water rights are unduly complicated. The multiplicity of small diverters--each with a different water right--on each stream creates a complex administrative problem.

Recommendation: Consolidation and combination of systems should be promoted in order to eliminate duplicate facilities and systems of sub-marginal size. This could result in better facilities, more efficient and fair management, and possibly improved water rights by developing storage and improving load factor. Immediate attention is justified.

This problem is one where little progress has been made in the past 60 years and one where the rewards would be great if it could be solved. It is extremely difficult to solve because irrigation systems are local monopolies and there is no competitive agency which can give the customer a taste of something better. Knowing

nothing better, the customer is content to go along in the same old traditional way. Furthermore, being human, it is difficult to get many irrigation farmers to believe that they are anything less than expert in all matters pertaining to water. Nevertheless, a great deal could be accomplished toward more efficient use of the water resource by achieving improved distribution systems.

Research and Education

The most promising public move, looking toward improved administration, is through well-considered research and education. This too, is difficult. Each system and each stream is a special problem which must be attacked individually. Often the human relations problem is more difficult than the physical one. Great patience will be required.

Recommendations: The practical way to proceed is for the Colorado State University Experiment Station, in cooperation with the Extension service, to employ several competent engineers to work with these problems on the spot, system by system. Confidence must be established first. The job would be half research, half missionary. It should not include preparation of engineering details; but it should include an objective study of available water, water rights, existing facilities, practices, and tradition. This problem is believed to be one of top urgency and one which has been grossly neglected.

In addition to research and education, some statutory regulation may eventually be desirable. But it would be foolhardy to try to pass such legislation before the public becomes convinced of its necessity. Such regulation might eventually include (a) a requirement that water be accurately measured at the

farm, (b) limitation of diversions to amount needed under efficient operation, and (c) weed-control measures. There is also the possibility of providing an incentive whereby the public might participate in the cost of rehabilitation or improvement if certain standards of design and efficiency were met. A particularly promising incentive would be to provide public participation in the installation of measuring devices. Whenever public funds are used for improvement under present programs, the disbursing agencies should use these as an incentive for improvement. For example, when the Bureau of Reclamation agrees to provide needed storage, this is the time to require the beneficiary systems to consolidate and improve their organizations, simplify their water rights, and rehabilitate their facilities.

Research Opportunities in Hydraulics Engineering and Fluid Mechanics*

The Civil and Irrigation Section of the Colorado State University Experiment Station has contributed much toward solving water and soil-resource problems.

Hydraulic engineering and fluid-mechanics research conducted in the past included work on snow runoff predictions, climatology, water measuring devices, flow dividers, evaporation, seepage, hydraulics of wells, stream-flow forecasting, and sediment excluders.

Current relevant hydraulics research investigations include:

(1) Hydraulics of structures to protect canals, highways, bridges, and farm land.

(2) Hydraulics of various configurations of highway bridge

* For details, request "Report CER 57 DFP-ARC" from Civil Engineering Section, Colorado State University, Fort Collins, Colorado.

crossings. This will benefit agriculture by reducing flooding of farm lands when water dams up behind bridges.

(3) Major emphasis is placed on hydraulics problems involving sediment transport in alluvial channels. This study will uncover valuable information for canal design.

(4) Study of current meters. This will lead to more accurate water measurement.

(5) Investigation of energy-dissipating devices. This study will protect canals from scour.

(6) Program to develop a lower-cost sediment lining for canals.

(7) Research on devices to keep coarse sand out of canals.

(8) Model studies of large dams.

(9) Groundwater hydraulics, law, and development.

(10) Hydraulics of drain tiles.

(11) A large volume of work on flow measuring devices.

What CSU Hydraulics Research Could Be Doing

Some of the areas of study that could be investigated by the CSU Hydraulics Engineering Staff if adequate facilities and budget were available are as follows:

(1) Water Measurement-- More accurate and simple devices for water measurement is a top-priority need throughout Colorado. CSU engineers have over 40-years experience in this field that could be utilized for developing devices, designing, and supervising installations and assisting in an education program.

(2) Canal Structures--Better drop structures and diversion structures at lower cost are needed. Experienced research scientists at CSU have been working in this field for several years. However, the program should be expanded several fold to get well-designed structures on Colorado's farms.

(3) Sediment Problems--Far from being solved are problems of sediment transport in canals, stable channel design, and exclusion of sediment from canals, power plants, recreation areas, and fish hatcheries. Transport of sand, coal, and foodstuffs through a pipeline in a water medium are related problems.

(4) Groundwater--Experienced men are available for field and laboratory studies of ground-water hydraulics. The current field project--recording water table elevations at a limited number of locations in the state for 28 years--needs to be greatly expanded. Basic research in ground-water law needs to be conducted on a larger scale.

(5) Problems of Seepage--Seepage from canals and the resultant drainage and alkali difficulties should be more fully investigated.

(6) Surface and Sprinkler Irrigation--Little is known about the hydraulics of the flow of irrigation water into the soil as related to method of application. Criterion should be developed that would permit better design of farm fields as to length and rate of water application, thus assuring maximum efficiency of water use. Economic studies comparing surface and sprinkler methods are needed.

(7) Evaporation from Soil and Water Surfaces--CSU is equipped for studying problems of evaporation from water and soil surfaces. Two wind tunnels, a wave basin, and an environment-controlled room are available for utilization, assuming some additional capital investment. Results could lead to cultivation practices that would reduce evaporation from the soils of drought areas, reduce dust blowing, and protect the soil. Furthermore, studies could be made on means of retarding evaporation from irrigation and municipal storage reservoirs.

(8) Phreataphytes--A major project should be initiated to eradicate native non-economic water-loving plants (willows, etc.)

(9) Lower Cost Canal Linings--Colorado loses much of its water resources, at least temporarily, because of the large seepage losses from canals.

A limited program in need of enlarging is underway in an effort to discover a low-cost canal lining that all irrigation districts could afford. The potential benefit to Colorado is immeasurable.

Recommendation: The listed hydraulics research opportunities are of sufficient promise in resource development to merit careful study.

On-The-Farm Management of Soil and Water

The problems associated with the development of water and its delivery to the farmstead have been discussed in the preceding sections of this report. Conservation of water on the individual farm is of comparable importance. Efficient use of water obtains maximum crop yield per unit quantity of applied water. Optimum

yield can only be approached through optimum timing and quantity of water application. These factors are, in turn, related to level of soil fertility, drainage, and salinity of the soil; type of plant and stage of growth; existing soil moisture level; evapotranspiration rate; and other related factors. The conservation of water and the conservation of soil thus are inseparable in theory and practice. Savings of both can be realized through proper soil-water-plant management systems. This saving must be achieved both to protect the state's vital food production capabilities and to meet ever-increasing competitive demand for water for other purposes.

Land Drainage Problem

Irrigation history is filled with examples of cultures founded on irrigated agriculture which succumbed to soil-deteriorating forces associated with inadequate drainage. Notable among these examples is the middle eastern valley of the Tigres and Euphrates Rivers in the region of Baghdad. The Salt River Valley of Arizona furnishes a parallel example in this country. In both cases, a flourishing irrigated agriculture suffered decline following unrestricted, unwise use of irrigation water.

A report of the Soil and Water Research Committee of the National Reclamation Association states ". . . in the decade from 1929 to 1939, over 1,000,000 acres of irrigated land in the western states were abandoned due to excess salt and alkali." O. W. Israelsen, a world authority on irrigation science, states ". . . an awakening of the American public to the fact that permanence of agriculture in arid regions depends vitally on more complete

development of irrigation science in relation to erosion control on irrigated lands, and in relation to the solution of the alkali (drainage) problem by more intelligent irrigation and drainage practices is evident."

Local examples can be cited which have a similar history. The Uncompahgre Valley and the Grand Valley in Colorado are two such cases. Both have considerable land area--once highly productive--which now produce virtually nothing. In both cases the problem has been one of inadequate drainage accompanied by the development of high water tables, saline, and sodium conditions and deterioration of the physical properties of the soils. Steinel in History of Agriculture of Colorado states that 100,000 acres in the Mosca-Hooper area of the San Luis Valley which were once irrigated and growing wheat have become unproductive because of high water tables and salt accumulation. Through improper management of water on the farm, seep and alkali spots may form not only on that farm but on adjacent land.

Present Situation: An inventory of lands needing drainage and the degree to which such lands are affected is difficult to obtain. The 1954 agricultural census states that out of 37,953,099 acres of farm land in Colorado, over 1,933,099 acres are "arid, waste or seeped" farm land. This census also reports 623,976 acres of land being drained by artificial means of which 304,364 acres are drained for the purpose of reclamation and alkali removal. United States Census data of 1950 indicate that of 2,872,348 acres of irrigated land, about 155,380 acres were in need of drainage. This estimate is very low compared to figures cited by Colorado Soil Conservation

Service officials who believe that crop yields on some 500,000 acres are reduced due to lack of drainage and that an additional 300,000 acres are severely affected by high water table and water logging.

Annual monetary losses to the economy of the state are estimated at $15-$20 per acre of affected land. If SCS estimates are used, over $1.5 million are lost annually due to poor drainage.

Acres now non-productive because of poor drainage will be needed. Forecasters of 1975 farm-production needs agree that the demand for food in the United States will increase in the next two decades at a rate of about 1½ percent per year. By 1975, this would require a total output 20 percent greater than at the present time. Thus, projecting ahead two decades, it is believed that a 30 percent increase in output will be required. Colorado would be expected to produce its proportionate share.

In terms of land resources, if yields are assumed to remain constant, the added land area necessary to furnish the projected needs would be 150 million acres. But the USDA report concludes that, with only 25 million acres of new lands in sight, U. S. must depend on technological improvement including drainage and reclamation to furnish the increased farm output.

Recommendation: If, as estimated, there are more than 800,000 acres of Colorado lands on which agricultural production can be increased or initiated by drainage and reclamation measures, it appears that long-run policy should include provision to encourage such measures.

Drainage in Future Water Developments: If the assertion is accepted that water supply and drainage are related, a problem of future public concern is apparent in the development of new lands

under irrigation and in provisions for additional water to supplement present supplies on existing irrigated lands.

In the latter case, attention must be given to the effects of new water supplies on the hydrologic balance in each area. This attention should consist of continual observation of drainage symptoms to detect the onset of drainage problems in new areas.

In the case of new development, attention must be given to the classification of lands on the basis of drainability. In either case, potential drainage difficulty must be appraised prior to selection of lands for development. Careful investigation is essential to the orderly and successful utilization of a limited water supply and to the conservation of a limited land resource.

For source-material references elaborating drainage problems, see appendix.

Good Reclamation Potential Indicated: An intensive study of methods of draining and reclaiming once-productive irrigated land in the lower Grand Valley west of Grand Junction is now in progress. Over 30,000 acres of land in this area--highly productive 35 years ago--are now submarginal or abandoned. The serious consequences of production loss prompted local groups to request technical assistance from the Agricultural Experiment Station and to undertake cooperative financial support in 1949.

Results of the studies have already shown that the land can be drained economically by wells properly located and that once drained, a high level of production can be obtained. Crop production on reclaimed experimental plots has exceeded the county averages.

Economic studies of the pump drainage indicate that an annual return of 20 percent on the initial investment can be realized. Such a return makes this system of drainage highly feasible.

Fortunately, in this instance, reclamation can be accomplished by simple leaching without addition of any chemical amendments. Once drainage is achieved, it is possible to reclaim the soil within a single season. Another reclamation study is underway for a much larger area in the San Luis Valley.

Effect of Present Irrigation Practice on Long-Time Production Capacity

As set forth earlier in this report, it is abundantly evident that the total irrigable land in Colorado exceeds the acreage for which water can ever be available. Unfortunately, improper use of water along with other unsound soil management practices have resulted in extensive and sometimes almost irreparable damage to many acres of land to which water has been allotted. The harmful effects of improper soil and water management practices are in addition to the drainage problem already discussed. They include:

Increase in Alkali Salts Including Sodium (Black Alkali): In practically all irrigated arid regions of the world, an increase in alkali acreage has accompanied the development of irrigation. Recently, it has been estimated that more than 800,000 acres of irrigated land in Colorado are affected to a sufficient degree by soluble salt (including sodium) to restrict yields. Some of this alkali has accumulated through excessive use of poor quality irrigation water high in salt and sodium. Contributing to the alkali accumulation problem has been the application of water to land which should never have been irrigated. This situation resulted from a lack

of knowledge of soil conditions pertinent to irrigability before the water was developed. Rapid deterioration of these soils through accumulation of salts was inevitable. (See also the discussion of drainage problem.)

Deterioration of Tilth (Physical Properties of the Soil): Evidence of tilth deterioration is observed in an increased tendency of the soil to crust, formation of puddled, cloddy soils, and slow infiltration and percolation rates of water during irrigation. Such deterioration reduces crop yields; reduces intake rates of water; increases time, labor, and cost of application; and loses water through evaporation and runoff.

Decrease in Fertility, Especially Nitrogen: The increase in crop yields brought about by irrigation, results in more rapid use of soil nutrients. But, at the same time, excessive amounts of plant foods are removed by leaching and erosion when improper soil and water management practices are followed. Such losses are sustained with no compensating return. Unnecessary loss in fertility through poor water management practice means reduction in yields or cost of plant-food replacement above what would be needed with good management.

Decrease in Efficiency of Applied Water as Related to Low Fertility: Many factors affect the efficiency of water use. Among them is the effect of plant-food level of the soil. One CSU Experiment Station study has shown that the application of 24 acre-inches of water in five irrigations resulted in the production of 17.4 tons of sugar beets on moderately fertile land and 21.0 tons of beets on adjacent highly fertile land. The same

amount of applied water resulted in an increase of 3.6 tons of beets at the higher fertility level. Similar results have been obtained with barley. Recent work in the mountain-meadow area in northwestern Colorado has shown that 9.7 inches of applied water produced one ton of native hay on low fertility land; on adjacent fertilized land, one ton of hay was produced from the application of 6.0 inches of water. These results indicate that more efficient use can be made of irrigation water if fertility is maintained at appropriate levels. It is wasteful of water to irrigate land of low fertility--as, for example, if only 20 bushels of barley can be produced. Work on this type of water fertility relationship is essential to keep Colorado agriculture healthy and competitive.

Loss of Water Due to Over Application: Soils can hold only so much water. Application of more water when the soil moisture through the root zone is at the full moisture-holding capacity results in loss from the field as runoff or as deep percolation. Tremendous water waste is involved. Avoidance of this type of wastage can be partially achieved by the use of mechanical soil moisture measuring devices. These devices indicate the point of dryness at which the land should be irrigated. For example, an experiment involving the use of moisture-measuring devices to indicate the need for irrigation in a wet year showed that 22.3 tons of sugar beets per acre were produced from three irrigations; on adjacent comparable land, 21.8 tons were produced from only one irrigation. An insignificant difference in yield with a saving of 7.8 acre-inches of water per acre was made. Similar results

undoubtedly can be obtained on some other lands and in other years. The combined use of perfected moisture-indicating devices and proper land leveling (to facilitate the distribution of irrigation water) can effect a tremendous saving in irrigation water. It can make limited supplies go further, reduce erosion and nutrient losses from Colorado soils, and help meet future increased water demands (whatever their priority of purpose.)

Research for On-The-Farm Soil and Water Conservation

The importance of research and education in the improvement of water diversion and distribution has been discussed. Improvement of irrigation water use on the farm is also of paramount importance to a water and soil conservation program. Conservation of the water resource is in itself sufficient reason for a strong program relating to the proper on-the-farm management of water. Improper use of water on the farm leads to deteriorating soil conditions that are contrary to the public conservation interests. Moreover, misuse of water affects a user's neighbor as well as himself. It is believed that the on-the-farm problems heretofore discussed can be at least partially solved by an expanded and intensified research program. The savings of soil and water that could result from new basic knowledge are staggering. Basically, the direction of effort would be confined to two objectives:

(1) Application of new water to soils that show promise of productivity over a long period of years.

(2) Maintenance of productivity of land already under irrigation.

Soil-Water-Plant Studies: In order to suggest the scope of the irrigation program conducted at Colorado State University, a list of particularly relevant past and present research projects is given below:

(1) The best time to irrigate field crops.

(2) Residual carry-over of original irrigation on the succeeding crop.

(3) Studies on the effect of different temperature of irrigation water on crops (wheat, potatoes).

(4) Classification of soils.

(5) Reclamation of irrigated soils.

a. Deep soils of the Billings series in the Upper Colorado River Basin.

b. High water table and salts in the Mosca area of the San Luis Valley.

(6) Physical properties of soil as a means of identification of problem soils.

(7) Restoring fertility to land leveled for irrigation purposes.

(8) Mechanical damage to structure of irrigated soils through the use of heavy machinery.

(9) Studies on leaching losses of irrigated soils.

(10) Rate and method of irrigation in relation to rate of planting, crop stand per acre, and fertility level.

(11) Comparison of the utilization by cattle of hay produced under different methods of water management and fertility.

(12) Improvement of crops to make better use of soil fertility and water.

For references to elaborate these and other related projects, see the appendix.

Additional and Intensified Research Needed: Research is needed in the following areas:

(1) Development of accurate technics for determining, prior to actual application of newly developed water, the irrigability of soils (maintenance of productivity over generations).

(2) Determination of the chemical and physical limits of soils for irrigation in relation to various qualities of irrigation water (both pumped and river water).

(3) Perfection of a simple and practical moisture-measuring device to assist the farmer in determining the proper time to irrigate.

(4) Development of methods and technics to prevent the deterioration of tilth (physical properties) of irrigated soils and to improve the tilth of damaged soils.

(5) To develop improved, efficient methods to reclaim saline and sodium (alkali) soils.

(6) It is important to know the changes in soil properties that result from rotation sequence of crops and such management factors as irrigation, fertilizer, species of plants, and harvesting methods. This will determine what water management practices should be followed for different combinations of water quality, fertility level, soil type, cropping, and

and climate--the practices which will obtain maximum crop yield per unit of water applied.

Education--A Corollary to Research

The irrigation farmer's principal task in using irrigation water is to store moisture in the root zone of his soil. No method of application permits 100 percent efficiency in this task. Some loss of water is unpreventable. But great strides toward increased efficiency are possible. Even with present knowledge along the lines of needed additional research, much can and should be done to teach efficient use.

These directions of educational emphasis for on-the-farm water use are recommended:

(1) Proper circumstances for use of sprinkler irrigation.

(2) Proper circumstances for use of surface irrigation.

(3) Difference between availability of water and need of water for efficient irrigation.

(4) Limits of soil "storage" of water. Frequently more water is applied than the soil will hold.

(5) Water requirements of crops.

(6) Methods to determine when irrigation is needed.

(7) Land leveling and design of water distribution systems for individual farms.

(8) Individual adoption of advantageous irrigation practices proven through experimental work.

Recommendation: Strong public policy in support of research and education at the state level is urgently needed. This should include all aspects of soil and water conservation. The Colorado

Agricultural Experiment Station and the Extension Service have long been engaged in activities of this nature, but their efforts have been inadequate in view of the magnitude of the problem. Since voluntary action by individuals must be relied upon to obtain adoption of improved conservation of water and soil, research and education must be used. The Department of Natural Resources should be in a position to promote both. There exists a great potential for improvement.

DRYLAND AGRICULTURE

Present Status of Eastern Colorado Dryland Farming

The Eastern Colorado dryland farming area is one of the principal agricultural sections of the state. Income from winter wheat generally ranks first among individual crops produced in the state. In addition, considerable income is derived from sorghums, corn, barley, and other small grains and related livestock production.

Good soil and water management practices are vital to successful farming over the entire area. In the southern half, where the climatic hazards for crop production are greater, ineffective soil and water management and cropping practices generally cause serious soil deterioration problems. This problem area section was a part of the widely publicized "dustbowl" which received national attention during the drought of the 1930's and again in the 1950's.

An examination of the basic resources of eastern Colorado provides some insight into the reasons for the agricultural instability of the area.

In about 63 percent of the eastern plains no attempt has ever been made to bring the land under cultivation. This portion is discussed in the "Plains Range-Livestock" section of the report. The remaining 37 percent of the area can be divided into (1) that portion which is capable of supporting dryland farming without encountering serious soil deterioration problems when effective soil and crop management practices are followed, and (2) that portion which is not suitable for farming except under most favorable

moisture and management conditions. It is the latter acreage that has led to public concern for the conservation of soil resources of the area. (See the Land Resources Area Map in Appendix for a detailed description of soil resources and limitations.)

The productivity of any soil and the problems encountered in its management, are conditioned by the climate of the area. Climate involves many component parts, average and extremes of temperature, wind velocities, length of frost-free period, type of precipitation, and others. The climate of eastern Colorado is of a "continental" type, with most of the precipitation occurring during the period of April through September. Precipitation is the dominant climatic factor influencing dryland farming production in eastern Colorado.

Four facets of precipitation are of particular importance, average annual precipitation, seasonal distribution of the precipitation, variations in annual precipitation, and intensity.

The average annual precipitation in the area varies between 12 and 18 inches. In general the lowest precipitation is found in the area just east of the mountains. Precipitation increases slowly as one moves eastward from this low precipitation "trough." (See page I-16.)

The seasonal distribution of rainfall is generally favorable for the production of winter wheat and other winter and early maturing small grains. In seasons when summer rains occur, warm weather crops like corn, sorghums, millets, and certain forage grasses are produced successfully. Both types of crops are favored in some years. The monthly rainfall distribution shown

for crop reporting district No. 9 (see insert on graph, page III-4.) is typical for the "continental" climate of eastern Colorado.

More important than the average amount or distribution of the precipitation is the variation around this average. The average annual precipitation in southeast Colorado from 1930 through 1955 is also shown by graph, page III-4. The high during this period (26.7 inches) was recorded in 1942. This compares favorably with the average precipitation in the western edge of the corn belt. But in 10 of the 25 years, the precipitation was 12 inches or less; in three of the 25 years it was less than 10 inches. The chances of raising a grain crop under the latter conditions are very poor.

But consideration of the variability of precipitation does not tell the whole story. It ignores the all-important sequence in which the above-average and below-average precipitation occurs. A sequence of dry years brings most of the economic stress and resource damage.

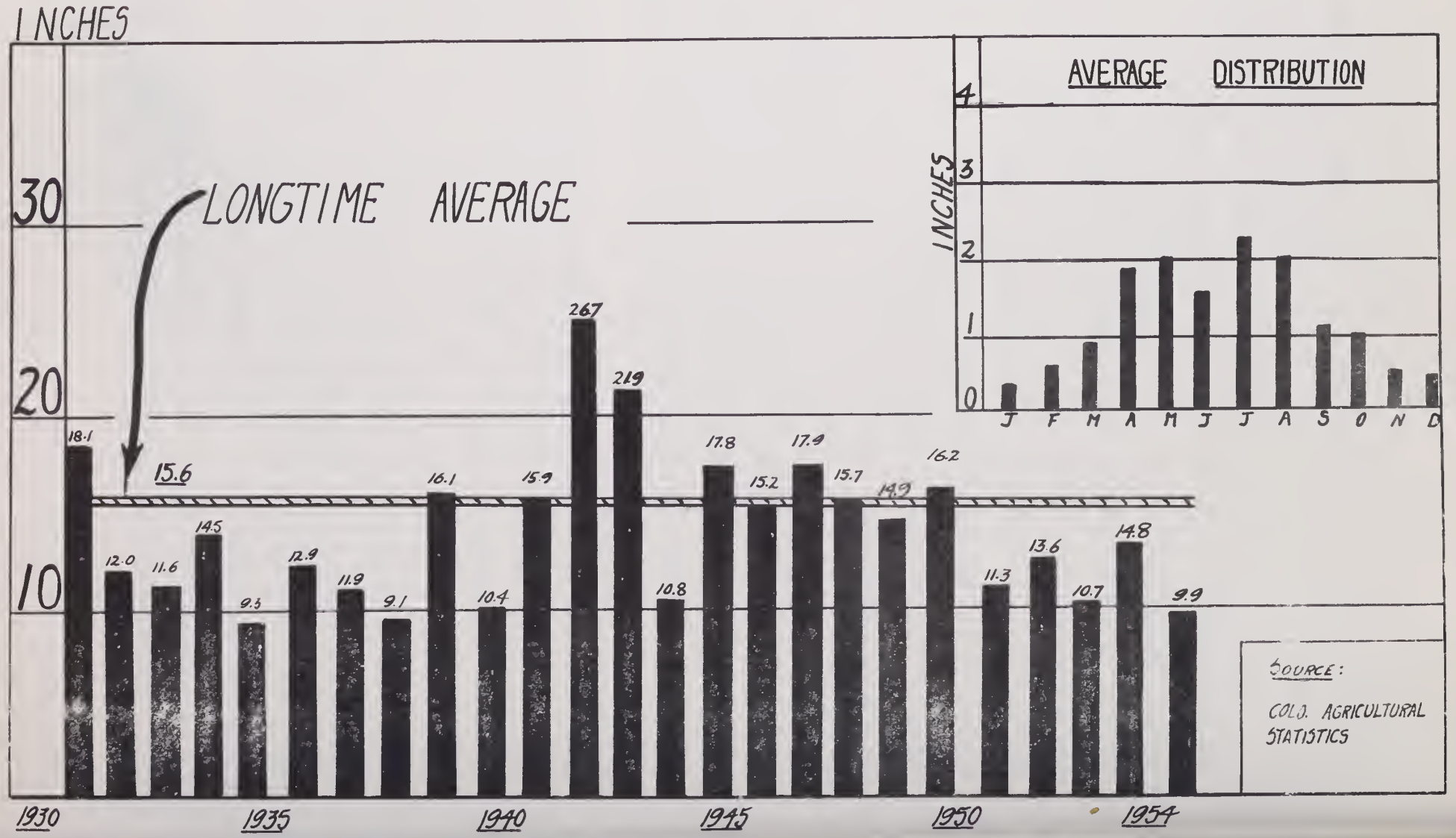
Maintaining a stable agriculture in an area where a year of above-average rainfall and a year of below-average rainfall alternated consistently would not present many serious problems. Helpful moisture could be carried over in the soil. Feed and cash reserves could also be carried over for the dry year. Under these conditions, a predicted precipitation could be estimated from a limited number of observations. A fairly good guide to production probabilities could be developed.

Attempts have been made to develop a statistical measure that would indicate the tendency for "bunchiness" in precipitation

Precipitation Record

Southeast Colorado Counties

(Crop Reporting District No. 9)



variation. Using the limited data available, Clawson computed a coefficient of variability sequence for a large number of western weather stations. He found a strong tendency for years of above average (and years of below average) precipitation to "bunch" in eastern Colorado.

If we combine a tendency for "bunchiness" with an annual average precipitation already near the lower limit required for successful wheat production, much of the difficulty encountered in establishing a stable agriculture is explained.

During a period of wet years, farmers begin to rely on sufficient moisture as "normal" and to plan their farming operations accordingly. Acreage of inter-tilled crops is expanded with excellent temporary results. Profits are high on relatively small units. Land values begin to reflect the mirage of excellent profit opportunities, thus adding to the temptation to crop land unsuited to continued tillage.

A series of below normal precipitation years then results in extreme economic difficulties. Feed and cash reserves are exhausted, livestock inventories are reduced, dry-plowed land is subject to wind erosion, and those who incurred heavy financial obligations during the wet years find payments difficult to meet. Local government and school finances and rural town business conditions reflect the farmers' plight. Available evidence indicates that this kind of periodic economic instability characterizes a considerable portion of eastern Colorado.

Dryland Farming Problems of Public Concern

If farmers of the area were able to adjust successfully to climatic conditions, there would be no reason for public concern or action. But widespread distress conditions during periods of drought indicates failure to make successful adjustments.

The public becomes concerned when there is definite evidence of deterioration of the basic soil resource. Few who have traveled through eastern Colorado in recent years would deny the presence of serious soil damage caused largely by wind erosion. The change in the fertility of soil which accompanies erosion is difficult to evaluate because few quantitative field tests have been made. Soil erosion by wind causes loss of plant nutrients by physical removal of soil organic matter and non-aggregated silt and clay particles.

Wind and Water Erosion

The damage by wind erosion, however, is not confined to reduction of soil fertility. Native plant food in the soil is a valuable resource. It becomes useful to mankind only when transformed into agricultural products. Environmental conditions and hazards which accompany active wind erosion prevent full utilization of the potential capacity to produce. Some of the more important reasons why wind erosion greatly accelerates soil deterioration and so reduces the productive capacity of the land are:

(1) Wind erosion tends to accelerate itself because soil gradually becomes more sandy in texture and consequently

more subject to action of the wind.

(2) The physical condition of the soil deteriorates.

(3) The soil becomes highly susceptible to surface crusting, causing high loss of water by surface runoff.

(4) Unstabilized fields require extra control operations and so may not be in readiness for the operator to take full advantage of the production capacity when precipitation is favorable.

(5) Use of heavier machinery becomes necessary for the more complex and intensive operations required to control wind erosion and expenses involved in such operations increase.

During periods of serious blowing extensive damage by soil deposition occurs to homesteads, crops, native pastures, roads, railroads, fences and other property. Atmospheric dust is a health hazard to both people and livestock.

An accurate estimate of loss caused by wind erosion is difficult. The Soil Conservation Service estimates of such damage for selected counties in eastern Colorado for 1956-57 are as follows:

County	Land in Farms (Acres)	Serious Wind Erosion Damage 1956-57	Percent of Land In Farms Showing Wind Damage
Kiowa	815,000	428,000	53
Crowley	420,000	216,000	51
Lincoln	1,500,000	720,000	48
Adams	687,000	252,000	37
Prowers	1,000,000	262,000	26
Cheyenne	845,000	176,000	21
El Paso	1,240,000	250,000	20
Weld	2,180,000	404,000	19
Morgan	745,000	131,000	18

Soil removal by water erosion in eastern Colorado also occurs, especially on the sloping hardlands. Surface runoff of water from torrential rains causes loss of both soil and water in eastern Colorado.

Fluctuations in Production and Income

Detailed figures are not available to indicate the fluctuations in income that have occurred in recent years. But figures are available on the production of the commodity that makes up a large part of dryland farming income in the eastern plains area. The following shows a striking variation in production of wheat in three eastern Colorado counties during the period 1948-1954.

WHEAT PRODUCTION AND VALUE

3 Sample Eastern Colorado Counties

1948-1954*

	Phillips County			Kit Carson County			Baca County		
	Acres harvested (1000 A.)	Prod. (Mil. bu.)	Value ($Mil.)	Acres harvested (1000 A.)	Prod. (Mil. bu.)	Value ($Mil.)	Acres harvested (1000 A.)	Prod. (Mil. bu.)	Value ($Mil.)
1948	144	3.3	6.3	260	5.4	10.4	303	6.1	11.6
1949	126	1.9	3.5	235	3.0	5.7	329	6.1	11.2
1950	123	2.8	5.7	258	3.1	6.2	76	0.4	0.7
1951	126	2.6	5.7	182	2.2	4.6	132	0.9	2.0
1952	163	4.4	9.2	323	5.5	11.4	87	0.7	1.5
1953	117	2.3	4.7	277	3.3	6.8	82	0.3	0.7
1954	108	2.1	4.5	182	0.9	2.0	44	0.2	0.5

* Compiled from Colorado Agricultural Statistics, 1948 through 1954.

More than 30 times as much wheat was produced in Baca County during the wet 1948 and 1949 crop years as in 1954. The value of the crop shows similar variation. The 44,000 acres harvested in 1954 was roughly one-eighth of the 329,000 acres harvested in 1949 and the 303,000 in 1948.

Although the variation in wheat production in Kit Carson County was considerably less than in Baca County, it is certainly of sufficient magnitude to jeopardize stability. Wheat production ranged from a low of .9 million bushels in 1954 to a high of 5.5 million bushels in 1952.

Phillips County probably has the most favorable combination of soil and climate in the area for wheat production. The production record shows 1.9 million bushels of wheat in 1949 and 4.4 million in 1952.

Governmental and Institutional Instability

Not the least problem associated with historic instability of plains agriculture has been that of maintaining solvent governmental services and school facilities. Extreme fluctuation of income during the drought of the 1930's led to wholesale tax delinquency and to drastic reduction in revenue for these purposes. The more recent drought was preceded by a number of years of good production and a high level of agricultural prices. This, coupled with federal drought disaster aid, prevented recurrence of a calamitous situation in recent years.

As this report goes to press, the drought appears to be broken. However, it must be reiterated that duration of adequate moisture periods are always uncertain. Neither is it an untruth to suggest that moisture relief in the latest instance arrived in the nick of time to forestall serious governmental and institutional financial problems.

Public Measures Affecting the Area

Federal Programs

The federal government has initiated many measures designed to relieve distressed conditions in agriculture. And the great plains area has been singled out for special treatment in a series of disaster relief measures. These have included emergency credit, emergency feed programs, a stepped-up soil survey program and paradoxically, even emergency flood relief. Financial resources of these programs have been so great that efforts by states to promote orderly resource development are dwarfed wherever federal programs are in conflict with a state program. A brief review of federal programs now operative will reveal sources of potential conflict.

The Price Support Program: The price support program for agricultural commodities was designed to alleviate depressed agricultural income. Of the supported commodities, only wheat is grown in large quantity in eastern Colorado. The program has been partially successful in raising incomes of wheat producers. But acreage allotments have been based in large measure on the cropping history of the individual. This provided a strong incentive for farmers to build up as much wheat acreage as possible in non-allotment years in order to establish a "history" of wheat production. This discouraged efforts to return marginal acreage to grass. At the same time, Agricultural Conservation Program payments have been offered as inducements to seed cropped land to grass. Thus the goals of different federal programs often have been contradictory as well as overriding because of their "dollar" backing.

The Soil Bank: The Soil Bank program, initiated in 1956, has not demonstrated effectiveness to date in securing any sizeable land use adjustments in Colorado The "acreage reserve" phase of the program induced some farmers to reduce wheat acreage in the summer fallow area. However, part of this land was planted to other crops. The "conservation reserve" phase induced the "retirement" of 490,000 acres, but most of this acreage was made up of small parts of many farms. A program with the sole objective of eliminating soil blowing might require complete retirement from crop production of farms on highly erosive soil, while leaving other farms on less erosive soils in crop production.

Agricultural Conservation Program: The Agricultural Conservation Program has been somewhat more effective in encouraging conservation measures. Under this program, farmers have been reimbursed for a part of the expense incurred when undertaking conservation measures. This provides a financial inducement for farmers to follow practices deemed desirable. The Soil Conservation Service has provided technical assistance in implementing this program. Lack of provisions to safeguard maintenance of conservation practices in ensuing years reduces long-range conservation effectiveness of the program.

State Programs

Colorado has not demonstrated financial "willingness" required to provide direct financial aid to farmers for carrying out programs of soil conservation. Thus it appears, that this means of effecting resource use may be left largely with the federal government. But the state can, and does, influence the pattern of resource use within its boundaries through its support of re-

search and educational institutions, its power to tax and disperse state revenue, and its power to pass restrictive legislation.

A positive program within the state should also do much to influence federal policy, even though it would not control or override that policy.

Research: As has already been indicated, climatologic conditions seriously affect other means of achieving agricultural stability in the dryland farming area. Even so--assuming (1) that people will continue to own and operate this land, (2) that the federal government will pre-empt the financial inducement field, and (3, that regulative action by the state is only to be used when the public interest clearly supersedes the interest of private citizens--it becomes necessary for the state to pursue a course aimed at finding facts (by research) to promote greater stability under existing climatic conditions.

Dryland research began with the establishment of the Plains Substation at Cheyenne Wells in 1894. Intensive studies on crops and soils problems of the area were initiated in 1907 at the Central Great Plains Field Station at Akron which was established by the USDA. It has always operated in close cooperation with the Colorado Agricultural Experiment Station. Principal problems first studied included climate, water requirement of crop plants, adapted crops and crop varieties, crop rotations, soil cultural methods, and organic fertilizers. Research results from this station have already done much to assist dryland agriculture in Colorado. The principal emphasis of the work at this station was changed in 1956 to soil and water conservation problems in the

dryland areas.

The Eastern Colorado Range Station was established near Akron in 1951 to study dryland range problems. Adaptation of grass and legume varieties and methods of reseeding and maintaining dryland pastures have been studied. Further reference to the work at this station is made in the Plains Range-Livestock part of this report.

The Southeastern Colorado Branch Station was established near Springfield in Baca County in 1955. This station is strategically located to study area soil and crop management practices and to find solutions to water conservation and soil blowing problems. Emphasis is being placed on practices that will make maximum use of the limited moisture received for crop production. Studies already undertaken include crop rotations, sorghum cultural practices, sorghum breeding, grass seeding, methods of fallow (particularly stubble mulch tillage), and available subsoil moisture at time of seeding as it affects winter wheat production.

The Experiment Station is cooperating closely with the Soil Conservation Service of the USDA in carrying out the accelerated program of soil classification in the Great Plains area. (See Soil Surveys in Appendix.)

Laboratory studies by Colorado State University are also designed for specific application in the plains area. For example, wind tunnel studies are being conducted to determine the behavior of the atmosphere near the earth's surface. Supplementary studies in an environmental controlled room are adding to our knowledge of the rates at which water is evaporated from soil surfaces and the

factors which affect this evaporation.

Education

Through its staff of county agricultural agents, and of agricultural specialists, the CSU Extension Service attempts to keep the farmer informed of experimental results that affect agricultural production and land-use. The problem of stability has recently been studied intensively on a group basis. During 1956 "Farm and Ranch Guides" were assembled and published in seven counties in southeastern Colorado. Others are in the process of development. These guides reflect the group thinking of experienced farm and ranch leaders who have survived adverse conditions in their areas. Specific farm and ranch management recommendations are made to aid operators in adjusting to the variable conditions that characterize the area. In addition, many field demonstrations are conducted each year in the various climatic and soil zones to show the best varieties and species of crops, the effect of fertilizers on crop growth, and the most effective and soil-conserving cultural methods.

If, as hoped, conservation of soil and water under dryland agriculture is to be achieved on a voluntary basis, farm people must receive education regarding every potential for improved practices.

It is not possible in this report to list or appraise all state legislation that might have a bearing on land use and land-use adjustments. However, it may be pertinent to list major types of land-use legislation commonly employed by states in promoting orderly development and use of the land resources. A special

report by an interbureau committee of the United States Department of Agriculture includes the following major types of land-use legislation as falling in this category:

1. A state rural-zoning enabling act that authorizes counties and other appropriate local units of government to adopt rural-zoning ordinances. Colorado has such an act.

2. A group of statutes to improve the workings of the water laws--particularly in the western states--to promote efficient and conservational use of water. This group probably includes new legislation dealing with the conservation of ground-water supplies. (See discussion in Irrigated Agriculture.)

3. Legislation along the lines of the soil conservation district laws already in effect in Colorado and most of the other states.

4. A statute or statutes offering a procedure for revising the structure of rural local units of government. There is an urgent need for intensive study of such legislation in Colorado.

5. Legislation to simplify existing procedures for the collection of delinquent taxes and the acquisition of a reasonably sound state or county title to chronically tax-delinquent lands. Tax delinquency has not been a major problem in Colorado in recent years.

6. Provision for state purchase of lands in the interest of land-use adjustment. A careful study is justified in Colorado for last-resort use.

7. Authorization of an appropriate state agency (a) to examine and classify lands that come into public ownership through

tax delinquency or other involuntary routes; (b) to make again available for private use lands found to be appropriate for that use; and (c) to administer the remaining lands in accordance with their best use. Careful study is justified in Colorado in case large-scale ownership through tax delinquency should develop at some future date.

Section 5 of the 1937 Colorado Soil Conservation Act, as modified by the 1941 and 1945 General Assemblies, embodies the type of legislation visualized in items (1) and (3) as listed above. Although this legislation has experienced some difficulty in administration and enforcement it does represent a concerted effort to ameliorate a serious land-use problem through state legislation. So-called "grazing," "sod-land," and "blow-land" ordinances have been enacted by soil conservation districts under the provisions of this enabling legislation.

Pump irrigation for land that previously was dryland has spread rapidly in some districts. The ground water law recently passed in Colorado is an attempt to promote orderly ground water development and use. Its effectiveness in achieving this end is yet to be determined. The existence of a State Water Conservation Board also provides a means by which the state can, and does, implement a program of water conservation. Vesting the State Engineer with water enforcement functions centralizes the function of settling disputes among alternative water uses and users. This problem and recommendations regarding it are treated in greater detail in the Irrigated Agriculture part of this report.

Items 4 through 7 are proposed interlocking solutions to problems arising under conditions of acute distress. To date, distress

periods that have occurred in eastern Colorado have improved before a comprehensive plan for state action could be devised and put into effect. The half serious statement that "droughts are of too short a duration to achieve a permanent solution" has an element of truth. We must recognize, however, that it is difficult to secure public support for control measures during a period when no drought exists.

For references elaborating dryland farming problems see the Appendix.

Recommendations

Recommendations for action rest on these assumptions:

(1) It is assumed that private ownership of agricultural lands by individuals will continue to be dominant in Colorado as well as in American agriculture.

(2) Only when the pattern of use developed under this system of ownership and control jeopardizes the health, safety, or welfare of the general public does the state become responsible for taking action to protect its citizens. The point at which such jeopardy becomes critical must be determined as a requisite to resource policy determination. Such determination should be undertaken by the Department of Natural Resources.

There are few farming areas in the United States where the operations performed on a plot of ground have more chance of social implications than in the dryland farming section of the Great Plains. It is impossible to confine within the farm boundaries the soil damage and dust storm hazards that result from poor farming practices. This may make it necessary to limit freedom of management to some degree.

Recommendations for Colorado's dryland are as follows:

1. Maintain an adequate research and educational program to provide the soil, water, plant, and economic information needed for wise decisions by farmers in the area and to aid the Department of Natural Resources in recommending land-use policy.

Promise for more effecitve use and saving of the soil and water resources in the dryland area lies in a continuous intensive search for new fundamental principles and methods of culture and crop production. Underlying all such research should be the idea of living with the environment by increasing the efficiency of limited moisture supplies and stabilizing both "normal" and "problem" cultivated land against wind and water erosion. Additional and intensified research needed to solve these problems includes the following:

a. Summarize past, present, and future climatic data into 24-hour-period patterns of amount and intensity of precipitation, wind velocity and direction, and evaporation. The summary would prepare a more accurate "effective precipitation" zone map for the area. (See section on climate.)

b. Continue work toward making more effective use of the limited moisture received, such as (1) studying the effect of plant food supply; (2) increasing moisture on certain lands at the expense of controlled runoff to adjacent lands; (3) breeding more drought-resistant crops; (4) improving tillage and seeding methods and machinery adapted to

soil type and climate; (5) further develop improved cropping systems; (6) investigate the principles of evaporation and methods for its reduction; and (7) broaden experimentation of methods of fallow.

c. Improve soil structure (tilth) and methods of reducing deterioration of structure.

d. Intensify studies on methods of controlling soil blowing and water erosion.

e. Find methods of combating insect and disease hazards in the interest of better establishment of crops and ground cover.

2. Delineate problem areas.

The need for state legislation to promote land-use adjustments or regulate its use will be greater in some locations than in others and will be most obvious during periods of unfavorable climatic conditions. It is, therefore, necessary to have a system of classifying all eastern Colorado dryland by the type of use that can be carried on through time without endangering the health, welfare, or safety of the public.

Basic soil and climatic data are being assembled under a program of soil survey and classification now being carried on by Soil Conservation Service in cooperation with Colorado Agricultural Experiment Station (see appendix.)

The Soil Conservation Service classifies land into eight types on the basis of need for conservation measures. These classes are called land capability classes and are one of the guiding determinants of the Land Resources Areas map (see ap-

pendix). The same basic data could be used for other types of interpretive classifications for other purposes. Support should be given to implement and complete the basic soil survey as soon as possible. Full use should be made of these data by state officials if it is decided that control legislation is needed as the basis to:

a. Define areas now in crops which can remain in crop production. On land designated as permanent cropland, the primary function of the state is to promote an environment conducive to the establishment and maintenance of farms of a size and type adapted to the conditions of the areas. Specific state actions should include (1) maintenance of a state tax structure that encourages rather than inhibits needed land adjustments and (2) maintenance of a close working relationship with federal officials responsible for programs in the area to facilitate compatability and consistency of state and federal programs. Within an area generally suited for cropland, there are small tracts unsuited for cultivation which should be returned to grass or some other form of permanent cover. State programs, along with existing federal programs, should be designed to facilitate this desired land-use adjustment.

b. Define areas now in crops that should be retired permanently from crop production.

Although the area of land now in crops designated as unsuitable for crop production will probably never constitute a very large portion of the total cropland in

eastern Colorado, this is the acreage that may require control measures. In so, research by qualified soil scientists should be conducted to provide the facts needed to identify the nature of such areas beyond any reasonable doubt. Then steps should be taken to assure that such areas are permanently retired from crop production.

Such regulation would require a radical departure from the historic policy--the individual would not be assured maximum freedom of action. Careful study of two means of achieving desired land-use adjustment is recommended:

Expanded use of voluntary group action ordinances by land owners in the area.

More positive control action by the state.

Local Group Action: Land owners should be encouraged to take group action in controlling land abuses in these critical areas. The required legislation for the initiation and enforcement of land-use ordinances already exists. The legal requirements have been tested in the courts. Local groups have acquired experience in their administration. In spite of some difficulties encountered in administering such a program, effort should be exerted to expand the use made of this tool. It does have certain advantages over the alternative means of achieving the same end. The chief advantage lies in its initiation and administration by local people based on experience and experimental evidence. It is also less costly to the state than alternative solutions. The main

disadvantages of this method of solving land-use problems are that it is slow, cumbersome and difficult to obtain consistent enforcement and may therefore fail to achieve the stated objectives.

Direct State Action: In critical areas where the local people demonstrate inability to secure the necessary adjustments in land use, the state may decide as a last resort to remove the problem lands from crop production. The local people may fail to act because of apathy, because they have not separated fact from fancy, or because they are not financially able to make the needed adjustments. Under these conditions, careful investigation of need for action along the following lines is recommended:

(1) Establishment of a state body, or authorization for an existing body, to purchase lands in the problem areas and to make the needed land-use adjustments. The same body would logically administer lands that might be acquired through tax delinquency.

(2) The lands so acquired to be examined and classified as to their potential for restricted use under private ownership in a manner that would not endanger public health, safety or welfare.

(3) Lands re-sold to private individuals to contain restrictive covenants in the deeds prohibiting any use of the land that would endanger the public welfare.

(4) Lands retained in state ownership to be administered in such a manner as to secure the maximum revenue to the state within the limits of desirable land use.

(5) In any case, where large blocks of land might move permanently into state ownership, it may be necessary to aid local units of government in adjusting to a reduced tax base. Such assistance should be given.

3. Intensive study of local government laws aimed at providing greater flexibility (a) by stabilizing governmental and institutional income and (b) by providing assumption of individual tax obligations consistent with time of best ability to pay as conditioned by climatic variations.

Wise use of resources requires a high degree of enlightenment on the part of those who are in a position to make decisions affecting resource use. This includes the farm operators, agricultural technicians, and the county, state, and federal officials. In this respect, Colorado State University offers leadership training facilities for now and in the future. University agricultural courses as well as experimental and adult education branches are designed to help.

PLAINS RANGE-LIVESTOCK OPERATIONS

Colorado's plains range-resources lie east of the front range and extend to the eastern border of the state. The plains range operations are considered separately from those of the mountains because of the great differences in land ownership, topography, and climate, which have resulted in distinct patterns and problems of rangeland use in the two portions of the state.

The topography of the plains is essentially level to rolling, with occasional mesas and breaks, lying at elevations of 3,500 to 5,500 feet above sea level. The native range consists of the shortgrass plains, the sandhills type, and sub-irrigated and intermittently flooded bottomlands.

In the plains area 65 to 80 percent of the annual precipitation is received during the growing season of April through September. Grasses are the dominant vegetation because of their particular adaptability to intermittent summer rains. The amount of precipitation received also has a bearing upon the farming and ranching problems in the plains. The annual precipitation varies from about 11 inches in the Arkansas Valley to about 17 inches in the southeastern corner and 18 inches in the northeastern portion.

The livestock industry is an important part of the agriculture of the plains area, and it is interrelated with the irrigated farms, dryland farms, and the rangelands. In the 1954 United States Census of Agriculture, five plains counties were in the ranking 100 counties in number of cattle and calves on farms, with Weld

County ranking second in the nation. Two plains counties are in the ranking 100 counties in the U. S. in number of sheep and lambs on farms. Approximately 63 percent of the plains area is in rangeland, the remainder in crops and grazed cropland. Interpolation of data from the 1954 Colorado Agricultural Statistics shows 24.5 million acres of land in the plains of which about 9.02 million acres are cropped. Of the cropland acreage, 560,000 acres are used only for grazing.

Ownership of Land

In the plains area the land is predominately under private ownership. Of the approximately 24.5 million acres of land in range and crops, 1,818,926 acres of grazing land are controlled by the Colorado State Land Board, 636,343 acres are under the jurisdiction of the U. S. Dept. of Agriculture in land utilization projects, and 177,493 acres are set aside for military uses (1950).

The land utilization projects in the plains are:

Fountain Creek	9,318 acres
Briggsdale	207,691 "
Springfield	265,537 "
Southern Otero County	162,797 "
Total	636,343 acres

Rangeland Use-Patterns

Plains ranches will generally fall into one of the following operational patterns: (1) ranches strictly dependent on range grass with no crops grown; (2) a combination of range grass with forage crops produced and used as winter feed for livestock; or (3) combinations of various types of dryland and irrigated cash

crops as the major enterprise with cattle or sheep making some use of areas in grass, irrigated pasture, crop residues, or annual forages. It is for this reason that the problems of the best use of both dryland and irrigated land resources are often interrelated with range use. Further details concerning the relationship between location of predominately livestock type of farming and cropland and rangelands are shown on pages I-17 and I-25 to I-29.

The following sections of the report are primarily concerned with range resource use and reference is made to the other resources only as there tends to be conflict. The problems which plains ranchers face arise out of (1) climatic limitations, (2) grazing management, (3) range revegetation needs, (4) soil and water conservation, (5) poisonous and noxious plant invasion, (6) and rodent and insect infestations. These problems together with recommendations for their solution are treated individually on the following pages.

Climatic Limitations

Fluctuating and extreme weather conditions markedly affect range vegetation and livestock operations in the plains regions. Frequent and recurring droughts, unseasonal cold temperatures, high evaporation, snowstorms, and high winds affect range herbage production, stock water supplies, length of the growing and grazing season, livestock production and losses. These in turn affect the stability and economic returns from ranching enterprises.

Table. Total annual precipitation, growing season rainfall (May 1-Sept. 30) and yield of forage grass herbage 1/ at Central Plains Experimental Range near Nunn, Colorado, 1940 through 1956.

Year	Annual Precipitation	Seasonal Rainfall	Herbage Yields
	Inches	Inches	Pounds
1940	14.81	11.75	578
1941	19.81	14.99	756
1942	11.69	6.11	747
1943	7.78	5.88	755
1944	8.17	4.41	600
1945	12.27	8.88	665
1946	11.79	8.33	687
1947	15.53	11.06	842
1948	7.92	5.82	474
1949	13.52	9.98	647
1950	11.90	9.75	464
1951	13.10	8.63	547
1952	14.10	11.14	689
1953	11.96	9.36	637
1954	4.89	3.23	188
1955	13.08	9.68	285
1956	9.72	6.61	439
Average	11.88	7.98	588.2

1/ Pounds air-dry hay per acre

The current year's precipitation, particularly that occurring during the growing season, affects height growth of range grasses, while the preceding year's precipitation affects the density or ground cover. Herbage production is related to both height growth and density. Studies have shown a high degree of correlation between the Agricultural Marketing Service's range-feed condition ratings in eastern Colorado and the combined current and previous year's precipitation. The effect of current and previous year's precipitation on herbage yields may be noted in the preceding table for the Central Plains Experimental Range. The first drought year in 1943 followed favorable growing seasons and showed less decline in herbage yield than for the second year of drought in 1944. The extreme drought year of 1954 drastically curtailed herbage yield, and there was a carryover effect in 1955 despite above-average precipitation.

The precipitation-evaporation (P-E) ratio is an index of precipitation effectiveness. P-E ratios under 0.2 generally indicate desert-like conditions, and ratios between 0.2 and 0.6 usually coincide with semi-arid grasslands. The following table of P-E ratios for plains stations reporting seasonal evaporation shows distinct differences between stations and a sharp decline during the recent drought of 1954.

Table. Average seasonal precipitation, evaporation, and P-E ratios for plains stations showing comparisons with the drought year of 1954. 1/

Station	Years	April-Sept. Precipitation Inches	April-Sept. Evaporation Inches	April-Sept. P-E Ratios
Fort Collins	1947-56 Avg.	10.17	35.46	0.287
" "	1954	5.56	42.30	0.131
Bonny Dam	1949-56 Avg.*	7.98	66.41	0.120
" "	1954	4.37	78.90	0.055
Pueblo-City Rsvr.	1947-56 Avg.*	7.35	57.34	0.128
" " "	1954	6.34	64.22	0.099
John Martin Rsvr.	1947-56 Avg.*	8.21	62.52	0.132
" " "	1954	7.42	68.65	0.108

* Average of existing records, data for a few months in certain years missing.
1/ Compiled from annual summaries of U. S. Weather Bureau Climatological data for Colorado

High evaporation rates during drought not only reduce the effectiveness of precipitation for the production of range forage, but they also curtail stock water supplies in surface reservoirs and stock tanks.

Climatic fluctuations cause considerable variations in the length of the growing season, period of green forage, and grazing season on the plains. Unseasonal cold temperatures and frost may delay the start of the grazing season by several weeks as, for example, in the spring of 1957. Moreover, growth of range forage may be terminated early by frosts or by protracted drought. The average frost-free period on the plains varies from about 140 to 170 days. (See map, page I-14.)

Heavy snowstorms often accompanied by high winds during the winter and spring periods frequently cause considerable damage to fences and livestock on the plains. The severe blizzard of March 23-25, 1957, in southeastern Colorado caused an estimated loss of 12,000 head of cattle and sheep. Baca County alone estimated a loss of around $800,000 in cattle, and the loss appeared to be one-third to one-half the total number of cattle.

Severe hailstorms in late spring and summer cause considerable loss of range forage and forage crops and have occasionally caused appreciable loss of livestock.

Lightning which accompanies summer thundershowers takes a considerable toll of livestock. Lightning and human carelessness occasionally set fires which destroy considerable acreages of plains range forage. In 1943, an estimated 200,000 acres of grassland were burned in northeastern Colorado.

Strong winds, particularly during dry winters and early springs may cause extensive soil drifting which may bury adjacent range forage, damage fences, and injure livestock.

Recommendations

Little is known concerning the relation of precipitation or soil moisture to actual range forage production and grazing capacity.

The Colorado Agricultural Experiment Station should undertake an intensive ten-year study at existing state and federal experimental ranges to determine whether forage production and grazing

capacity can be predicted accurately from precipitation or soil moisture. Such a study would require about $5,000 annually. If prediction proves feasible, it may be necessary to establish a cooperative state service to gather seasonal precipitation and/or soil moisture data for making predictions to range users.

At least one agricultural meteorologist and climatologist should be employed and associated with the Agricultural Experiment Station to organize and conduct research, in cooperation with the U. S. Weather Bureau, of value to agriculture and related industries

Grazing Management

It is important to the economy of individual ranchers and to the state that livestock production be maintained at its highest practical level. Experience has shown that maximum sustained livestock production can be obtained only through proper grazing practices on the range and through efficient feeding practices.

Foremost among the principles of management on eastern Colorado's ranges is that of adjusting livestock numbers to prevent overuse of the range resource. If a range is stocked too heavily, the native vegetation deteriorates, causing decreased forage, an increase of less desirable plants, decreased livestock production, and often considerable soil erosion. On the other hand, stocking too lightly fails to make use of forage, and total livestock production per unit of land is again decreased.

Recognition of these changes is used in the determination of range condition, which, in turn, is directly related to livestock

production. A survey made of cattle ranches in the Great Plains section of Colorado and New Mexico showed that ranches with ranges in good, fair, and poor condition, respectively, marketed 14.3, 11.2, and 8.9 pounds of beef per acre.

Other fundamental principles involved in obtaining maximum sustained livestock production from our ranges are using the range during the proper season as determined by its particular characteristics; grazing the range with the proper kind or combination of kinds of livestock as determined primarily by vegetation and topography; and obtaining uniform distribution of livestock over a range area by such means as distribution of water, salt, and fences.

Current Programs

Grazing management research programs are currently being conducted at two stations in the plains portion of eastern Colorado at the Eastern Colorado Range Station located between Akron and Sterling on the sandhills, and at the Central Plains Experimental Range at Nunn, on shortgrass vegetation.

Action programs, initiated by the Soil Conservation Service, the Bureau of Land Management, and the Forest Service (through the Land Utilization projects), have done much in demonstrating the beneficial effects of proper grazing management.

Needed Programs

Research on grazing management should be continued and intensified. Among the grazing management practices for which further information is needed are the following:

(1) Determination of the effects of various systems of grazing, such as deferred-rotation grazing, on range forage and livestock production, especially as a means of rehabilitating run-down ranges;

(2) Determination of the effects of various seasons of use on plains ranges;

(3) Studies of the effects of combined cattle and sheep use;

(4) Determination of new methods which will aid in proper distribution of livestock over a range; and

(5) Continuation and expansion of studies to determine the effect of various intensities of use upon livestock production and upon the range forage and soil resources.

Recommendations

(1) Certain areas in the plains do not have results to draw upon from experimental areas in similar climatic and soil areas. Notable among these are the areas in the 11- to 13-inch rainfall belts in an area approximately 100 miles wide extending southward through the state from the South Platte River. A state range experiment station is needed in this area to provide basic data on the best systems of range use, proper rate of stocking, and range management practices adapted to this low rainfall area. An experimental range area, similar in size to the Eastern Colorado Range Station would be required. An annual operations budget of about $25,000 would be needed.

(2) In conjunction with the grazing management research program, informational and educational programs should be intensified. A full-time range management extension specialist is needed. Livestock producer groups should be kept better informed of the varied research programs that are underway at the various experiment stations.

(3) Proper grazing use on state-owned lands should be assured through constant vigilance by the staff of the State Board of Land Commissioners. Continued effort should be made to assure that personnel with specialized training in range conservation be on the field staff which administers state-owned grazing lands.

(4) In order to provide a possible incentive for better use of privately owned range, a system of classifying rangelands for assessment purposes could be set up as recommended by Saunderson in Montana. Rangelands could be placed in 3, 4, or 5 classes, based on their productive ability, and assessed accordingly. The fewer the classes, the more likely is the low value rangeland to be assessed at about the same figure as better land. Accurate assessment would make it possible for the landowner to stock the range at the proper rate. Over-assessment would tend to bring about over-use. A study of the feasibility of such a plan should be made in Colorado.

Revegetation

During the early stages of dryland agriculture in eastern

Colorado most of the arable land was brought under cultivation for the production of cereal crops. Insufficient moisture, combined with soil drifting, resulted in low yields, particularly on poorer soil types, and large acreages were abandoned as early as 1936. For example, Weld County at that time had approximately 70,000 acres of abandoned lands in various stages of natural revegetation, and by 1937 about 20 percent of the cultivated land was abandoned in Washington County.

Abandoned fields are not only unproductive, yielding only a fraction of their forage capacity, but the drifting soil from them is also a menace to adjacent rangelands and farms. Natural revegetation is an extremely slow process. Studies of abandoned croplands in northeastern Colorado have shown that as many as 60 years may be required before original vegetation is replaced by natural means. Artificial reseeding or revegetation can establish a perennial cover much more quickly.

In addition to abandoned croplands, there are large acreages of marginal farmlands, largely wheat lands, that are best suited to a cover of perennial vegetation. On these areas yields are usually low and soil drifting is a constant menace. From the standpoint of resource conservation of soil and water these lands definitely should be returned to perennial plants.

Since the late 1800's when the range livestock industry had its beginning on eastern Colorado ranges, some areas have been subjected to destructive over-use and now are in such a depleted condition that improvement by natural means would be uneconomical.

Not only are these depleted ranges producing only a fraction of their capacity, but many also are suffering from wind and water erosion.

Among the primary benefits of successful range reseeding or revegetation programs are (1) additional forage for livestock production; (2) better seasonal balance of forage; (3) stabilizing of soils and reduction of runoff; and (4) relief of grazing pressure on adjoining native ranges during critical periods, thus allowing for their recovery and improvement.

Great increases in meat production have been noted in certain instances due to reseeding. Grazing studies on reseeded pastures on the Fort Collins Foothills Experimental Range, from 1944 to 1954, have shown the following average pounds of beef produced per acre: Tall wheatgrass, 89; Russian wild rye, 87; Intermediate wheatgrass, 66; Smooth brome grass, 45; Crested wheatgrass-smooth brome grass, 40; and Native range, 27. The foregoing results were obtained on better than average sites, and results on many range sites would not be quite so favorable.

Crops vs. Grass

One of the most difficult problems for a livestock producer, farmer, rancher or land administrator is to decide whether a given area should be planted to an annual crop or to a perennial grass. This problem is complicated because of the varying and unpredictable climatic conditions and economic returns from these respective crops. This dilemma has been further intensified by various federal farm programs and subsidies. Thus, in many cases,

under other than existing economic situations the most economical use could be made of these areas by returning them to a perennial forage cover of adapted species. The soil and water erosion that has resulted from many years of cultivation and extended drought are very obvious and are considered elsewhere in this report.

A recent report has shown that without subsidy, it would require five to six years to repay costs of range reseeding in Eastern Colorado provided the first attempt were successful. If the first attempt failed, it might require as long as 13 years to repay the costs. With the advent of the conservation reserve features of the Soil Bank program, the economics of seeding some wheat land back to grass is more favorable to the landowner than indicated above. The risk involved in establishing permanent grass cover is such that some form of assistance to the landowner appears necessary.

Current Programs

The problem of revegetation has been and is currently being studied by the Colorado Agricultural Experiment Station, the Soil Conservation Service, the Agriculture Research Service, and the Forest Service.

Among the primary problems currently being investigated are choice of species, season of planting, depth of planting, seedbed preparation, and management after planting. Because of the nature of the work the interpretation and application of the observed and measured results may require many years. However, in relation to other range investigations, a relatively large amount of information

on reseeding applicable to eastern Colorado is available. (See references in Appendix.)

Research is also being conducted to show the value of reseeded pastures in balancing a year around forage supply. Shortage of forage is primarily an early spring problem, and thus this particular phase has received the greatest study although in some instances livestock are maintained all year on one or a combination of seeded pastures.

Needed Programs

As in grazing management studies, current research results of reseeding do not directly apply to certain areas in the state, notably the low rainfall areas of eastern Colorado. Ranchers need to know various chemcial and physical means of improving production on old seeded stands. Recent studies in shortgrass areas have indicated that treatments such as renovating, legume introduction, and fertilization may substantially increase production on old stands.

Since stands of most introduced species used in reseeding are at one time or another, usually during extended drought, inferior to native range plants, additional work should be undertaken to select, develop, and produce seed from strains of superior native plants. It would be desirable to experiment more with mixtures of species. Studies of this nature require long periods especially if one is to test the effects of various climatic cycles.

Recommendations

On state-owned lands, the present policy places the burden of

reseeding or other range improvements on the lessee. It is recommended that study be made to determine the feasibility of setting aside a certain portion of the revenue from state land leases to be used for protection and improvement of ranges, as is done in the case of lands under federal administration. Such a fund could be used for protection of state lands from fires, insect or rodent pests, or for range improvements such as reseeding or water developments.

Soil and Water Conservation

The soil is our basic resource, and water is the main factor limiting production on eastern Colorado ranges. Thus these two factors are of paramount importance and should be so considered.

Vegetative Cover

An adequate cover of range plants not only controls wind erosion but also is effective in reducing the adverse effects of raindrop impact, which is the starting point for water erosion. A total cover of live and dead material composed of short sod grasses of 1,000 pounds an acre is 80 percent effective in preventing erosion by raindrop impact and intercepts approximately 57 percent of the wind's force. If this cover is reduced by half, to 500 pounds an acre, then it is only 60 percent effective in preventing erosion by raindrop impact and will intercept only approximately 18 percent of the wind force. On the other hand, if this range cover is doubled to 2,000 pounds an acre, it will prevent 95 percent of the erosion due to raindrop impact and will intercept approximately 95 percent of the wind's force.

Precipitation is more effective where there is an adequate cover because losses from evaporation are reduced. A good cover of range plants is likewise effective in conserving and improving soils by providing surface and sub-surface storage, retarding run-off, intercepting water-borne soil materials, and reducing the abrasive effect of the water and its contents. Standing vegetation at the end of the grazing season greatly aids in increasing the amount of snow that is held on a range, thereby increasing the amount of soil moisture. The return of organic matter to the soil, largely through the roots of plants, has much to do with maintaining proper soil structure. Therefore, the return of greater amounts of organic matter to the soil increases the ability of that soil to absorb moisture--both in rate of absorption and quantity absorbed; and less is lost by destructive runoff. Thus, proper grazing intensity, which promotes maximum sustained forage production and which leaves an adequate cover of vigorous plants with deep and extensive root systems at the end of each grazing season, is in accordance with wise use of our soil and water resources.

Systems which divert excess runoff from its normal course and spread the water over level flats have been shown to increase forage production. Although water spreading is applied to rangelands primarily to control soil erosion and conserve moisture, other benefits include sediment retardation, increased forage production, restoration of ground water levels, stream flow regulation, and improvement of wildlife habitat. It has been estimated that in the western United States the total area of

of public land suitable for water spreading is around 3.5 million acres, of which about 750,000 acres have been developed. Stock ponds have a similar effect in that they also reduce excessive runoff and improve wildlife habitat. Stock ponds also provide additional watering places for livestock and thus may aid greatly in distribution of grazing over a range.

Other mechanical measures used to conserve water on rangelands include soil pitting, contouring, chiseling, terracing, and ripping. Soil pitting is accomplished by means of an eccentric disc or a large water-filled cylinder equipped with points and shanks to penetrate the soil to a depth of approximately 12 inches. Among the benefits attributed to soil pitting or "hole punching" are aeration, improved water catching ability, promotion of forage growth, and loosening up sodbound ranges. Contour furrows can be applied to slightly rolling non-sandy rangelands without specialized machinery. Ripping, chiseling, and terracing are more specialized practices applicable only to limited highly productive areas. From a conservation standpoint, land-use practices, supplemented by engineering structures, contours, pits, check basins, etc., as needed, are essential. However, nature is a persistent force, and, without a conservational pattern of land use, any man-made structures sooner or later must lose their effectiveness.

Conflicts and Relation to Other Interests Within Agriculture

Proper grazing intensity and measures taken to reduce destructive runoff may in some cases appear to conflict with certain

other agricultural interests. In certain areas, improved range conditions may partially deprive downstream water users of excess runoff which results from unwise use of our ranges. However, this runoff is not only silt and debris-laden, but it is also an undependable source of water. A more stabilized stream flow, a restored water table, and a better quality of runoff to be expected from improved rangelands should greatly outweigh so-called benefits of intermittent excessive runoff. A stable soil which promotes more even stream flow and runoff is a definite requirement from the standpoint of non-agricultural interests. Many are the stories of loss of human life, of flood damage to downstream communities, roads, bridges, railroads, and city water supplies.

Non-Agricultural Land-Use Conflicts

Agricultural land is a valuable resource, but with the increase of population pressure and expansion of urban areas it will become much more important. Conflicts sometimes arise when agricultural lands are converted to various non-agricultural uses, such as military installations, including ordinance depots, air fields, bombing ranges, etc. Less spectacular but possibly more common and more important when considered in the aggregate is the rapid increase in the acreage set aside for state and federal highway programs. Steeply sloped, unvegetated roadsides, cuts and fills are often the starting places for extensive gully systems and possibly infestations of poisonous and noxious plants. From the agricultural as well as the scenic standpoint it would be desirable to revegetate these areas with suitable perennial plants. In relation to these non-agricultural uses, of special

importance to the livestock operator is the need for proper fencing and an adequate number of crossings, access roads, and livestock underpasses.

Possible misuse of the range exists in relation to mineral and oil resources, especially from the standpoint of exploration activity and through unwise location of roads, etc. In certain limited instances, however, exploration for minerals may be beneficial to proper land use. Seismograph crews, for example, can make arrangements to leave some test holes unfilled so that windmills may be set up, thus providing livestock water.

Current Research, Education, and Incentive Programs

Land and water programs for conservation and development of resources take various forms, such as improved land-use practices, terraces, contouring, stock ponds, and very large dams and engineering structures. Although very little research is currently being conducted which is directly related to soil and water conservation, many existing projects are indirectly related. Research studies of any of the resource use problems such as climatic limitations, grazing management and artificial revegetation all have some measure of relationship to soil and water and these sections should be referred to. Agencies conducting research, which has a bearing on soil and water conservation on the range livestock operations of eastern Colorado, are the Colorado Agricultural Experiment Station and the Agricultural Research Service. Some studies of the Forest Service are also applicable.

The land-use programs undertaken by cooperators in Soil Conservation Districts or on Bureau of Land Management lands are very important in demonstrating the desirable effects of soil and water conservation measures. Resource conservation is becoming a more important and popular subject in our state's education system. However, in many of the primary schools its importance is largely dependent upon the personal interest of the individual teacher.

A local-state-federal program which is becoming more important in soil and water conservation is that provided by the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, and amended by Public Law 1018, 84th Congress). This act is described in detail on pages I-36 and I-37.

The principal federal activity pertaining to soil and water conservation on eastern Colorado rangelands is the Agricultural Conservation Program (See page I-39). Although the program varies somewhat between counties, federal assistance in range improvements related to soil and water conservation include the following:

(1) Improvement of vegetative cover on rangeland by artificial reseeding for soil protection.

(2) Controlling competitive shrubs to permit growth of adequate desirable vegetative cover for soil protection.

(3) Furrowing, chiseling, pitting or listing non-crop grazing land to prevent soil loss, retard runoff, and improve water penetration.

(4) Constructing wells for livestock water as a means of protecting established vegetative cover.

(5) Developing springs or seeps for livestock water as a means of protecting established vegetative cover.

(6) Installing pipelines for livestock water as a means of protecting established vegetative cover.

(7) Construction of permanent cross fences or drift fences to obtain better distribution and control of livestock grazing and to promote proper management for the protection of the established forage resource.

Benefits vary for these various practices and there are limits and requirements for each.

Federal loan assistance is available under prescribed conditions for range improvement purposes through the Farmers Home Administration. (See page I-42.)

Recommendations

The virgin soils which the white man found available for his use on this continent have been thousands of years in the making. Unfortunately only a few generations, and in some areas less than a generation, have caused widespread depletion. In many respects soil depletion is an insidious process, at times not readily recognized even by technical specialists. It is likely to become apparent to the man on the street only when the process of destruction has reached an extremely advanced stage. Therefore research should be intensified so that the physical and chemical changes in the soil complex may be recognized at early stages so that steps may be taken to prevent further deterioration.

Various agencies, both state and federal, have contributed much towards emphasizing the importance of soil and water conservation to the public. However, it would be desirable if these programs were intensified and better supported. Additional research should be undertaken showing the economic and physical losses due to soil erosion. Methods of soil and water erosion should be considered from the community or regional standpoint rather than from the individual standpoint. Participation in small watershed programs should be encouraged. More local groups should be made aware of these programs. Furthermore, attention should be given to educational and research activities. What needs to be done cannot be separated from the operating mechanics of doing the job and from getting the job incorporated as a part of the thinking of the people who are directly involved.

Resource conservation should become a standard subject to be taught in our public schools. It should be considered in the primary schools as well as the secondary schools. Youth programs, such as 4-H clubs and vocational agriculture classes, dealing with range conservation should be emphasized and increased in number.

Soil stabilization may be a key factor to safety on highways. For this reason, soil disturbance, caused by highway construction should be stabilized. Methods for such stabilization are now known and should be written into construction contracts.

The Problem of Poisonous and Noxious Plants

Poisonous or noxious plants can impair the value of rangelands in localized areas in the plains. For example, there is a serious infestation of St. Johnswort (Klamath Weed) on the Rocky Flats area south of Boulder. St. Johnswort has been found in Colorado for only a relatively short time but has already spread to cover approximately 6,000 acres of rangeland. Cases of poisoning of livestock by whorled milkweed, suckleya, and cockleburr have been sporadically reported. Under certain weather conditions, plants such as pigweed and Kochia, not generally poisonous, may cause nitrate poisoning in livestock.

Low value range plants which tend to replace permanently more valuable forage species are termed noxious plants. In this category are such plants as yucca, cactus, snakeweed, and sand sagebrush.

Current Programs

Research which would have to be termed only exploratory in nature has been initiated on the control of St. Johnswort near Boulder. The research is being conducted by the Colorado Agricultural Experiment Station in cooperation with local ranchers, the Extension Service, and the Soil Conservation Service. There is a real need for expanded research on the St. Johnswort, since this weed has become a serious pest in California, Oregon, and Washington, and threatens to spread in Colorado.

The Colorado State University Extension Service and the Soil Conservation Service are assisting in the exploratory research

and have acquainted the local ranchers with the acute hazard of permitting St. Johnswort to spread.

The Colorado State Department of Agriculture has initiated biological control of St. Johnswort by the introduction of beetles.

Colorado State University workers and those in other states have conducted research on the control of sand sagebrush. Control methods with 2,4-D are now well established. There remains the problem of determining under just what situations control is economical. Under certain conditions at Woodward, Okla., chemical control of sand sagebrush has proved to be economical.

Considerable research has been conducted on control of cactus and yucca, but little concerning snakeweed. The economics of the control of these noxious plants has not yet been established, and any control other than grazing management is of doubtful value.

Recommendations

(1) Research and Education: Colorado State University, the State Department of Agriculture, the Soil Conservation Service, and other interested parties should start a concerted attack to eradicate St. Johnswort in Colorado. Further research is needed to perfect techniques of control. As soon as the best control measure is determined, education and action programs could be initiated.

More educational work should be done to acquaint ranchers with the problem of whorled milkweed. Research on the economics of controlling sand sagebrush should be started by the Colorado Agricultural Experiment Station as soon as feasible.

(2) State Policy for Remedial Action: Local ranchers should be given all the assistance possible to eradicate the current outbreaksof St. Johnswort. Although it is only a localized problem, assistance under the ACP program in Jefferson County would be desirable, and provisions should be made to finance adequately further research by the Colorado Agricultural Experiment Station and to finance control programs by the Colorado State Department of Agriculture.

The Problem of Rodents and Insects

The amount of range forage lost to rodents and insects in Colorado each year is not known exactly, but often the loss is known to be a substantial percentage of the total forage produced. Jack rabbits, plains pocket gophers, prairie dogs, mice, grasshoppers, and harvester ants cause losses of economic importance.

Current Programs

The Colorado Agricultural Experiment Station currently is engaged in new research that will attempt to answer the question of the extent of forage lost to rodents and insects. Recent research has produced improved techniques for control of the harvester ant, grasshoppers, and the plains gopher. Methods for controlling prairie dogs have been perfected and are now in the action stage.

The Colorado State University Extension Service has recently published a bulletin on control of the pocket gopher and is carrying out an educational program, taking to the various counties

the techniques that have been worked out and giving demonstrations. The Extension Service and the U. S. Fish and Wildlife Service cooperate in programs of controlling prairie dogs and other rodents. Colorado State University and the Bureau of Entomology cooperate in making studies of potential grasshopper outbreaks and in getting this information to local groups.

Recommendations

Research and Education Needs: Much basic information on the activities and ecology of range rodents and insects is still needed to provide a basis for determination of economical control. The Colorado Cooperative Gopher Control Project is an example of a well-integrated study on all phases on one kind of range rodent. Similar coordinated research programs could well be initiated to study the other range rodents, such as jack rabbits, mice, and kangaroo rats.

The educational and action programs of Colorado State University and the Fish and Wildlife Service, although both well underway, should be continued and enlarged.

State Policy for Remedial Action: State policy can be of most assistance through adequate financing of research programs and participation in cooperative state and federal action programs.

References

References which are related to the discussions in this portion of the report are listed in the appendix.

Summary of Recommendations

1. An intensive study should be undertaken at existing research areas to determine possibilities for accurate prediction of range forage production and range seeding success based on climatic and soil moisture data.

2. An experimental range in the 11- to 13-inch precipitation belt of eastern Colorado should be acquired and operated to provide basic data on the best systems of range use, proper rate of stocking, and management practices suited to this low rainfall area.

3. A full time range management specialist is needed to help plan and execute educational and publicity programs that will help to put better range management practices into practice.

4. Inasmuch as the state has about 1.8 million acres of grazing land in the plains, it is recommended that personnel trained in range management be on the staff responsible for administration of state lands.

5. In order to provide incentive for proper rates of stocking rangelands, and to distribute taxes on rangelands more equitably, studies should be made of the feasibility of establishing three to five grades of grazing lands, based on potential productivity, as a basis for tax assessment.

6. Study should be made to determine the feasibility of setting aside a certain portion of the revenue from state land leases to be used for protection and improvement of the state's rangelands, as is done in the case of lands under federal administration.

7. Additional research is needed to determine changes in the soil complex in the early stages of erosion before serious deterioration takes place.

8. Local groups should be made more aware of the availability and benefits of small watershed programs.

9. Safety on highways may be affected by lack of soil stability. Seeding programs are recommended to accompany highway construction contracts and to stabilize existing trouble spots.

10. State assistance is needed for research and action programs to curb the outbreak near Boulder of St. Johnswort, a plant injurious to livestock.

11. Studies are needed to determine the economics of controlling sand sagebrush in the plains.

12. Additional research is needed to determine economical control of range rodents not as yet included in current research programs. Educational and action programs for the control of several species of range rodents should be intensified.

MOUNTAIN RANGE LIVESTOCK RANCHING

General Description

A vast and sometimes colorful, sometimes dismal appearing tract, rich in spots, seemingly barren in others, bounded by Wyoming, Utah, New Mexico and the western edge of the Great Plains, constitutes the mountain range resource area of Colorado. It covers approximately three-fifths of the total area of the state.

Range Definition

By way of simple definition, range is here considered as those land areas which are covered primarily with grasses and shrubs on which both domestic and wild animals can graze for part or all of their food supply. This resource throughout the mountain area is highly variable as to kind and quantity, but each type fits logically into the existing scheme of livestock production.

Topography

The topography varies from the low, semi-arid foothills of the eastern slope of the Rocky Mountains to the high alpine areas above timberline and downward again on the west through timbered slopes, foothills brush lands, to rolling sagebrush areas and finally to the desert lowlands of extreme western Colorado. Many local variations such as the San Luis Valley desert-type range are interspersed geographically.

Climate

Climate is as variable as the topography. Precipitation ranges from less than eight inches annually in the deserts to as

high as 40 inches in some of the alpine areas. Much of the precipitation falls in the form of snow during the winter months. This fact is reflected very definitely in the type of agriculture employed.

Temperature and Length of Growing Season

There are also wide variations in temperature and length of growing seasons. The latter varies from a short 60 days in the high North Park area of Jackson County to as much as 166 days in the lower mountain valleys of Garfield County.

Economic Importance

This highly variable area is extremely important in Colorado's overall economy. Here rise the headwaters of four major rivers -- the Arkansas, Rio Grande, Platte, and Colorado -- supplying not only the needs of Colorado for domestic, irrigation and industrial water, but also much of the water needs of neighboring and downstream states. Timber and wood products, oil and gas, oil shale, coal, minerals and recreation facilities add greatly to the state's resources inventory.

The livestock industry, with the cattle and sheep population accounting for 49 percent of the total for the entire state, is the principal agricultural enterprise. The annual cash income from livestock and livestock products in the area approximates $146 million (based on a ten-year average, 1945-1955). Livestock operation are completely dependent upon the range resource, both private and public.

Land ownership in this mountain area presents a rather complex picture. Public lands comprise approximately 61 percent of the total with administration divided as follows:

	Acres
United State Forest Service	13,728,564
Bureau of Land Management	8,590,605
Bureau of Indian Affairs	730,513
National Parks and Monuments	517,820
Colorado State Land Board	1,012,174
Miscellaneous	681,385
Total	25,261,061

Of this total the following acreages are used for grazing:

United States Forest Service	6,000,000
Bureau of Land Management	8,222,605
Bureau of Indian Affairs	685,000
Colorado State Land Board	923,919
Miscellaneous	253,571
Total	16,085,095
National Parks and Monuments (big game grazing only)	517,820

The remaining 39 percent (lands in farms and ranches) comprises 14,076,524 acres. A total of 84 percent of the lands in farms and ranches, or 11,927,017 acres, is grazing land.

Distinguishing Management Factors

The producers of livestock and livestock products must plan their operation to furnish an adequate forage supply for each 12-month period. Their individual resources of land and water are their primary concern as they must depend on these for the major portion of their annual forage needs and must show production adequacy, in most cases, to be eligible to use public lands.

Grazing lands, both public and private, are normally classified by their season of use; namely, spring-fall (the same range

may be used in early spring months and again in the late fall months), summer, and winter. Topography, climate, and location have a very direct bearing on this classification.

Privately owned rangelands must provide for the bulk of the grazing load in spring and fall and to a considerable extent in summer. The present pattern of use on some public range lands, particularly those administered by the Bureau of Land Management, provides for some of the spring-fall grazing load.

The ranch operator must remove livestock from his fields and meadows early enough to allow a maximum growing period for hay and crops to provide winter forage. The necessary date for this removal precedes considerably the date when summer ranges are ready for grazing. Likewise, in the early fall when livestock must be removed from summer range, forage growth may still be taking place in fields and meadows and must be maintained as long as possible to fill winter forage needs.

Spring-fall range thus becomes one of the greatest needs and most important factors in management plans. Fortunately the gap can be filled by research, proving the possibility of greater mountain meadow production from reduced acreage, improvement of range capacity by controlling the invasion by undesirable plants, reseeding and water spreading, and better range utilization by controlled grazing.

The winter feeding period is a critical one in mountain livestock operations. Sufficient forage, usually in the form of hay, must be produced during the short summer growing season. This period, when little native forage is available to livestock, varies from about three months in some of the low-altitude valleys with

mild climate to as long as six months in the high-altitude valleys and parks with their severe climate and heavy snowfall. Livestock feed requirements thus may vary from a half to over two tons of hay to winter a cow or its equivalent.

Most hay production in the mountain area depends on irrigation. Consequently, an adequate supply of water during the growing season, particularly after the spring runoff period, is of major importance.

Crop residues and aftermath (secondary growth made after harvest) provide some winter grazing when not covered by snow. Actual winter range use by livestock in Colorado's mountain area is limited mostly to sheep, occuring principally on the so-called desert type areas near the western border. In some very limited areas, cattle can make use of range forage throughout the year.

In all types of livestock wintering operations, some supplements to both range and harvested forage are usually needed. Such supplements are principally high protein concentrate and, occasionally, grains. Their provision through both production and purchase is an important part of the overall management plan and a very definite factor in the cost of production.

Principal Operational Problems

There are many problems constantly facing the users of this important range resource. Many of these are of long standing.

Land Use

The past pattern of land use, often one of abuse, is still a big factor in keeping the range's carrying capacity of both domestic and wild animals far below its potential. The same

factor limits values of the range for water production, recreation, and, in some cases, timber production.

Scars have been left by haphazard exploitation of mineral deposits in the early mining days on the eastern slope and the ravages of earlier-day transient livestock herds in the high mountains of the western slope and the western desert areas. Past misuse is apparent in the lack of valuable forage plants, in the scars of erosion, rapid loss of water and topsoil, and general unsightliness.

Periods of drought, overgrazing by domestic and wild animals, attempts to farm land not suited to cultivation, unwise exploitation of mineral and timber resources, land abuse by recreational interests, and even natural succession lead inevitably to a weakening and disappearance of the most valuable varieties of grasses, herbs, and shrubs on grazing lands.

As plants most desirable for forage and for watershed protection begin to thin out, they are replaced by plants of less value. In large areas of the Western Slope at lower elevations, the principal invader is sagebrush; at higher elevations, oak brush or pinon and juniper. Undesirable weeds of many species, some poisonous in nature, show a rapid increase on injured rangelands. Controlling these invaders and rebuilding the grazing and watershed values of the land is a tremendous problem.

Animal Life Hazards

Another constant threat to the production value of rangeland, regardless of past use and condition, is animal life.

The problem of rodents in range agricultural areas of the western states, including Colorado, is extremely critical. Due to the marginal nature of the lands and the number of rodent species, economical control is difficult.

It has been conservatively estimated that pocket gophers alone infest at least four million acres of the most productive range lands in Colorado and cause an annual damage of $2,850,000.

The kinds of damage by rodents vary. Pocket gophers, prairie dogs, rabbits, and other rodents remove desirable forage species and promote the growth of undesirable species. They burrow in ditches, meadows, pastures, and ranges, causing water loss and erosion. They reduce efficiency of agricultural operations by reducing carrying capacity and by loss of time in attempts at controls.

Mormon crickets and grasshoppers build up periodically (particularly during dry years) and can destroy most of the available forage. Harvester ants have been known to take as much as 40 percent of a range out of production with their nests. White grubs are a problem in some areas. They cut the grass just beneath the soil, thus destroying the range.

Water Shortage

Water shortage caused by drought in the mountain range country is another constant threat. Nearly every year finds the livestock operator experiencing some degree of seasonal water shortage. This may be a late season lack of irrigation water so necessary for adequate winter forage production. It may be a lack of snow to furnish water for sheep on winter range. It may be a lack or failure of water development

structures on seasonal ranges. It may be an extended drought causing a serious reduction in forage production.

Cost

Range improvement through reduction of undesirable plants, rodents, and insects followed by a program to increase desirable forage species from either natural or artificial reseeding involves problems of direct cost as well as the indirect costs due to non-use during the improvement period. Structural changes to improve range conditions also involve costs. The low returns per acre very often make it difficult or impossible to adopt improvements if the economics of costs and returns is the test.

Winter Feed

One major operational problem is the dependence of the mountain livestock industry on spring-fall range adequate to fill in seasons before the summer range is usable and again before winter feeding is necessary, and on providing a large enough supply of forage for winter feeding. In the majority of cases, it is necessary to allocate irrigable and tillable acreage to production of winter forage. In most areas -- because of topography, climate, and past pattern of use -- the range available for spring-fall grazing is marginal land with low productive capacity. Alternative operational plans are few and expensive.

Importance of Public Rangelands

The public lands supply a very substantial percentage of the total annual livestock forage requirements. Consequently, ranch management throughout the area is influenced by national forest grazing policies, changes in the public domain and unclassified areas, state leasing policies and public domain policies regarding

other uses than grazing.

Because of its physical characteristics, the public lands range is principally suited to grazing. It is mostly arid or semi-arid. Much of it is desert valley, mesas, plateaus and high mountains, broken by rough canyons and rugged desert terrain. Soils on much of the area are thin, poorly developed and some are highly alkaline. Only a small portion of this land is suitable for crop production, but nearly all of it produces forage plants that are edible by domestic livestock and wildlife. The forage may be grass, shrubs, or weeds native to the area. Introduced species of plants are to be found in only a few locations.

The public rangelands still bear scars incurred during decades of unregulated grazing use. The normal wearing down and building up of the earth's surface known as geologic erosion has been speeded up by partial removal and change in the protective plant cover. Deterioration of about half of the total range area has occurred to a point where range management alone may not protect the land from further depletion or restore it to its original productivity. Special land treatment measures beyond the capacity of landowners must supplement range management to halt accelerated soil erosion and secure a permanent cover of vegetation.

According to the best estimates now available, a large percentage of public rangelands are in a state of severe to critical erosion, additional lands are eroding moderately, and only a small percentage are in a condition of slight to no erosion. Thus the major portion of public rangeland is contributing to downstream sedimentation and presents some of the most critical

watershed problems of our western river basins.

The heavy toll of range soil taken by wind and water erosion is largely the result of a depleted plant cover. Perennial grasses and browse plants affording the greatest protection to the soil have been removed through drought, overuse and fire. Their removal has encouraged the invasion and spread of undesirable brush and trees until many millions of acres of once productive rangeland are occupied today by sagebrush, oak brush or junipers.

These species furnish little protective cover for the soil and lack the mulch-producing qualities of grasses. Instead, the soil between the plants is exposed to the erosive forces of wind and water. The porous topsoil is soon eroded away leaving a pavement-like surface rendered even more impervious by the sealing effect of silt particles. Rain or snow falling on these areas has little opportunity to penetrate in amounts adequate to promote the re-establishment of grasses without the help of artificial methods.

The many variations in soils, topography, elevation, degree of slope, aspect and the wide variety of vegetative types within most individual allotments tend to result in uneven use by livestock, ranging from heavy use to no use at all. In order to get proper use of the range, by elevational zones and on area and vegetative types not naturally preferred by livestock, a great many range improvements, especially fences, are needed. Neither the Forest Service, Bureau of Land Management, nor the grazing permittees have been able to finance more than a small percent of the improvements needed.

Agency Policies on Public Lands

Indian Land Policy

Indian land leased to non-Indians is managed by the Indian agencies, and leases are adapted to local situations. Most trust-alloted land is leased to individuals on the basis of competitive bids. Permits are used in connection with some of the tribal land, but individual allotments are usually made. Indians are encouraged to use their own land and are given preferential treatment in such cases.

Other Agency Policies

The Bureau of Land Management, State Land Board and Forest Service all play an extremely important role in the mountain range areas of Colorado. Their functions and policies are described in detail in the Introduction.

Use Conflicts

Major and minor conflicts in resource use exist both within agriculture and between agricultural and other interests.

Transient Grazing

Use of higher altitude private and leased lands (both range and irrigated meadows) for transient grazing during the summer months is on the increase. This type of seasonal use as opposed to maintenance of a year around livestock operation may make economic sense under many conditions. Although it may present no particular problem in wise use of the resource, this use may present a serious sociological problem and a tax problem to the county. Does this type of operation reduce the number of permanent residents in the county? Does it reduce the number of persons gainfully employed throughout the year in the agricultural

industry? Does the carrying of transient livestock on the county tax rolls for only a few months, or perhaps not at all, seriously reduce county income from the personal property tax on livestock? These are some questions that need answers.

Sheep vs. Cattle

The infamous days of wars between cattlemen and sheepmen have long since passed into history. Decisions must still be made, however, by operators of private lands and administrators of public lands as to which ranges can best be used by sheep and which by cattle.

Recreation and Sports

The rapid influx of vacationers to the mountain wonderland of Colorado is multiplying the opportunity for private landowners to capitalize on water and scenic resources for cabins, homesites, lodge developments, and guest ranch operations. This land is taken out of production, and the forage consumed by "dude string" horses means fewer meat animals.

Trespass by careless, over-enthusiastic fishermen during the summer and by hunters in the fall plagues many landowners in the mountain area and in some cases damaged land resources result.

Some forests now graze more big game than domestic livestock. Because their forage preferences are somewhat different, game animals tend to use much rough land not suited to livestock. Nevertheless, there is competition because grazing habits overlap. This is especially true between cattle and elk.

As a general rule, if big game animals are limited to the number that their winter range will safely carry, there is a minimum of conflict.

Some lands now used by domestic livestock will be closed in the future to provide camp and picnic areas, resorts and summer homes. The area and forage involved is relatively very small.

On much of the land administered by the Bureau of Land Management, the competition between big game, mainly deer and livestock, is acute. This is because of winter concentration of deer on these lands. In some areas, hunter access is quite a problem.

Prospecting and Mineral Development

The search for and development of mineral products, accelerated tremendously by the increasing demand for uranium, poses a problem of land use and surface damages on private as well as public lands since much of the former has passed into present ownership without the mineral rights.

There has always been some conflict between grazing and mining in the active mining districts of the state. If and when extensive coal and oil-shale deposits are developed, conflict can be expected to increase.

Water Production, Use and Development

If good management is practiced on rangelands; that is, if grazing is regulated and managed so that the forage crop is perpetuated or improved and the soil is held in place, there should be very little conflict between actual water production

and grazing. Grazing should not impair either the amount or quality of water produced. In many places we do not yet have this type of management. Some areas now being grazed will need lighter use and a few will have to be closed completely in order to keep silt out of water supplies.

Storage and trans-location of water will take some areas out of grazing use. The fear of contamination on municipal watersheds has closed some range and will continue to do so until these municipalities have adequate water treating facilities.

Timber Production

Good timber stands usually produce little forage. Many old timber burns are now being grazed. With better fire protection and the gradual restocking of old burns either naturally or by planting, these areas will gradually be lost to grazing use.

State Lands Not Involved

No particular conflicts in use exist with regard to state lands. The state retains oil, gas, and mineral rights on state lands and can lease at any time for exploration and development of these resources without regard to surface leases. In case of all such development, however, even where surface acres have previously been sold, the developer is forced through fees and bonding to settle for surface damages.

No state owned grazing land has been leased in recent years to be broken out of sod. Sales are carefully screened to prevent this misuse.

Research Contributions (Past and Current)

Past and current programs of research have added and are adding tremendously to our knowledge and application of rangeland and related resource management and improvement measures.

Mountain Meadow Production

In the past six years the Experiment Station of Colorado State University, with assistance from the federal Agricultural Research Service, working on test plots in Gunnison, Routt and Park Counties, has developed principles and methods of production on mountain meadows that will help ranchers increase per-acre production from meadowland for winter feeding. At the same time this research provides for better range conservation by producing meadow hay for feed during the time necessary for preserving and improving rangeland. Not only has the yield of hay been increased by as much as five times, but nutritive value has been improved, water conserved and soil fertility increased.

Sage Brush Eradication

Small scale trials in Moffat, Grand, Gunnison, Garfield, and Rio Blanco Counties have shown that eradication of sagebrush followed by reseeding has paid handsome dividends in the form of more meat or wool an acre and greater ease in handling livestock. Grazing capacities of ten to 40 acres per cow-month have been increased five to twenty-fold by sagebrush eradication and reseeding. At the Great Divide Experimental Range, beef production has been increased 10 to 30 pounds an acre following sagebrush control and reseeding. Other range test plots with sufficient

grass to make reseeding unnecessary have had their grazing capacity doubled or trebled within a few years by sage eradication and good grazing management. Similar results from initial trials have been obtained after eradicating oak brush, weeds and other undesirable species.

Management Planning

Research, already producing tangible results, has not been limited to the above. Management plans for handling both the rangeland and livestock for maximum production and gains have been developed.

Seed Varieties and Cultural Practices for Reseeding

Widespread tests have indicated the best grass varieties, seedbed preparation methods, seeding dates and seeding equipment for regrassing rangeland by reseeding.

Various methods and machines for range furrowing or pitting, a proved procedure for increasing water penetration and moisture holding, have been developed, tested, and classified as to effectiveness and economy of operation.

Water Structures

Structures for impounding, diverting and spreading water for greater conservation and use by livestock, and effectiveness in forage production have been developed to fit most existing areas and conditions.

Rodent Control

Present programs, both research and action, are reducing the seriousness of invasion of rangelands by predators, rodents and insects.

A cooperative study was initiated in 1955 by the Colorado State University Experiment Station, the Fish and Wildlife Service Research Laboratory, and the U. S. Forest Service Rocky Mountain Forest and Range Experiment Station to investigate the pocket gopher and effective means of its control. Also during this time a number of field demonstrations on control by known methods have been arranged by Colorado State University Extension personnel and some 5,000 acres were treated for control in 1956 under Fish and Wildlife Service supervision.

Cooperative Agency Programming

Range management research on public lands is carried on by the U. S. Forest Service-Forest and Range Experiment Station and the federal Agricultural Research Service, often in cooperation with state experiment stations. This coordinated cumulative research has produced many extremely beneficial results. It recognizes that forage is an important resource. How to make the best long term use of this resource is the main challenge of research in range management.

Some of the problems under study are (1) how to evaluate range conditions, (2) how to restore depleted ranges, (3) management of reseeded ranges, (4) how to minimize the effects of drought, (5) how to control undesirable brush, (6) how to control weeds and poisonous-plants to increase forage production, (7) how to get better or more uniform utilization of forage by use of fences, (8) trails, salting, water development and herd management, (9) how to correlate big game and domestic livestock grazing, and (10) how to correlate grazing with watershed requirements and hold soil erosion to a minimum.

Specific Pest Control Programs

Mormon Cricket Control

Range Mormon cricket and grasshopper control programs have been conducted in areas where outbreaks have occurred. These programs werefinanced by the U. S. Department of Agriculture, the State of Colorado and individual ranchers. The organization for such programs has been the responsibility of the Extension Service at Colorado State University.

Harvester Ants Control

Demonstrations on the control of harvester ants have been conducted in several counties. This activity needs to be expanded.

Predators

The Federal Fish and Wildlife Service, with cooperation from the Colorado Department of Agriculture, Colorado Game and Fish Department, Bureau of Land Management, most Colorado counties, and the various state livestock associations, have kept coyote, bobcat, mountain lion and predator bear numbers within reasonable bounds.

Prairie Dogs

Prairie dog control constitutes the largest rodent control operation in Colorado. The Fish and Wildlife Service, again with the cooperation of the Colorado Department of Agriculture, Forest Service, Bureau of Land Management, Colorado State University Extension Service and most Colorado counties, is continually reducing the prairie dog infestation in the state. Some 244,000 acres were treated for prairie dog control in 1956 and 39,000 acres were treated for ground squirrel infestations.

Educational Contributions

The educational process through information disseminated by meetings, demonstrations, printed material, and mass communications media has kept pace with research results.

Extension Education

County agricultural planning committees and livestock producers, assisted by county agricultural agents and extension specialists, have developed extensive range management programs in a few counties. Such programs are based on a detailed inventory of the county range resources, complete listing of the range use problems, enumeration of the elements of range management and information needed to solve the problems, and a course of action with methods of implementing that course, including range judging contests, printed and visual material, experimental data and plots, establishment of local demonstrations, cooperative programs, record analysis, and final evaluation of results.

Youth activities, which seek to instill a true appreciation and understanding of the range resource and its management in the minds of resource users and managers of the future, have been successfully initiated with 4-H Club and vocational agricultural students in several areas of the state. This program is growing and generating new enthusiasm. Effects often spread among adults who come in contact with the program.

Cooperative Contributions

Leading livestock operators and public land managers long have recognized the need for complete accord and agreement on range use and programs for range improvement. Much has been accomplished in this respect. A committee from the Colorado

Cattlemen's Association, public land agencies, and Colorado State University has worked long and hard to develop a handbook of standards and guides to range use, acceptable to and clearly understood by all.

Demonstrations

The same committee mentioned above, with assistance of local cattlemen's associations, county agents and others, has established a number of continuing demonstrations to show the relationship of proper stocking to range condition and livestock gains. In addition cooperative demonstrations on range allotment improvement on forest service grazing lands, involving joint efforts of financing and labor by users and the adminstrative agency, have been established. Advisory committees of grazing permittees are recognized by public land agencies as essential to wise administration. Old frictions and misunderstandings are gradually being eliminated by working together.

Incentives

Soil Conservation Service

A substantial acreage of mountain rangelands and mountain meadows need to be reseeded artificially to hasten vegetative recovery, increase forage production, and protect soil and watershed values. The Soil Conservation Service, working with soil conservation districts and individual landowners, provides technical assistance in (1) determining need for such plant materials; (2) establishing field plantings to evaluate adapted species and planting methods; and (3) encouraging the production

and collection of good quality seed. It further provides on-site technical assistance to individual landowners who have decided to reseed portions of their rangelands or mountain meadows as a part of their conservation plans.

Agricultural Conservation Program

Some of the conservation practices particularly applicable to rangeland improvement and for which cost sharing is provided under the ACP program are:

1. Initial establishment of a permanent vegetative cover for soil protection or as a needed land use adjustment.
2. Initial establishment of a stand of trees or shrubs on farmland for erosion control, watershed protection or forestry purposes.
3. Improvement of vegetative cover on rangeland by artificial reseeding for soil protection.
4. Controlling competitive shrubs to permit growth of adequate desirable vegetative cover for soil protection range or pasture land.
5. Furrowing, chiseling, pitting, or listing grazing land to prevent soil loss, retard runoff and improve water penetration.
6. Constructing wells for livestock water as a means of protecting established vegetative cover.
7. Developing springs or seeps for livestock water as a means of protecting established vegetative cover.
8. Constructing, enlarging or sealing dams, pits or ponds for livestock water as a means of protecting established

vegetative cover.

9. Construction of permanent cross fences or drift fences to obtain better distribution and control of livestock grazing and to promote proper management for protection of the established forage resource.

10. Constructing erosion control, detention or sediment-retention dams to prevent or heal gullying or to retard or reduce runoff of water.

11. Constructing spreader ditches or dikes to divert and spread water to prevent erosion, to permit beneficial use of runoff, or to replenish ground water supply.

12. Leveling land for more efficient use of irrigation water and to prevent erosion.

13. Reorganizing irrigation systems to conserve water and prevent erosion.

The Soil Conservation Service provides technical assistance in determining need, feasibility, and performance checking for designated conservation practices approved under the ACP cost-sharing program.

Farmers Home Administration

This agency provides loans for soil and water conservation, including such improvements as construction and repair of terraces, dikes, ponds, and canals for irrigation and erosion control structures. Also, pasture improvement, brush removal, land leveling, fencing, well drilling and the purchase of pumps and other irrigation equipment.

Multiple Use Concept

The whole vast and important mountain resource area must be managed and improved to provide the greatest amount of benefit to all people, now and in the future. No one use or interest -- water, grazing, recreation, timber, or mining -- can be given preference over the other except in specific localities best adapted to that use and then only in light of its relationship to the total benefits.

Public policy at the federal, state, and local level must be based on this true multiple use concept, pitting no one use or interest against the other and providing no special privileges to any one group of users.

Improved management, fire protection, and complete conservation treatment of public and private rangelands will halt further deterioration from accelerated soil erosion and unwise use, and will provide permanent protection for one of our important natural resources.

Fortunately rangeland improvement accomplishes, not the needs for one use, but rather all the needs required by the true multiple use concept; and we already know a good many ways to achieve improvement.

Conservative estimates place the increased carrying capacity potential possible from full development of the rangelands at 30 percent. This increase in forage will add stability to the livestock industry dependent on the use of the range.

With fully vegetated watersheds, complete erosion control

and restored ground water, stream flow from the rangelands will produce better regulated and more usable water for downstream domestic, agricultural, municipal, and industrial needs.

Reduced silt flows on the watersheds and stabilized stream channels will protect investments by extending the useful life of downstream reservoirs, power installations, irrigation works, and other water resource developments.

Detaining a portion of the excess runoff on the watersheds for later release will help prevent destructive floods on downstream property and improvements.

An increase in wildlife values has already been demonstrated with improved management of the rangelands. Further increases in these values can be expected with greater forage production and an abundance of well distributed water developments on the range.

The federal rangelands are by law accessible to the public at all times. Added recreational values would result from more wildlife, improved vegetative cover, and the development of special recreational-use areas. Use conflicts with livestock operators would be reduced.

Improvement programs need not conflict with full development of minerals, oil and gas, oil shale, and peat.

Recommendations

All problems and conflicts of public lands become problems of public concern. The principle of maximum use of the resource for the benefit of the greatest number of people for the longest

possible time makes this so.

Continuation of research programs on private lands to improve range carrying capacity, to improve production from mountain meadows and thus release more land to grazing, to develop additional spring-fall range for filling the seasonal gap, is of concern to the general public.

Likewise educational programs to carry the results of research to the custodians of the land, encouraging adoption of proved management plans, is a public opportunity and responsibility.

Cost-sharing, as an incentive to more rapid application of conservation programs and practices than would otherwise be possible, rightfully recognizes the public stake in agricultural resource improvement.

To solve these problems and assure maximum benefits in a policy of multiple use, certain definite needs must be met.

Principal Research Needs

Range research in Colorado should be directed toward (1) improvement of the resource, (2) more efficient use of available forage supplies in the production of livestock and game animals, and (3) proper correlation of grazing on rangelands with water production, timber production and recreational use of the same areas. To implement these studies current research programs should be continued, some work on current problems expanded, and research on new phases initiated. Some of the most important needs are listed below.

Sheep Range Improvement Studies

Very little study has been made on the utilization and management of western Colorado's extensive sheep ranges for continued or improved forage production, for more efficient use of the forage crop and for providing proper watershed management.

Intensive research, particularly on spring-fall and winter ranges is needed to determine range response under various stocking intensities; the correlation of lamb crop percentage, lamb gains and fleece weights with range condition; general management practices, improvement factors and watershed and big game values.

Need for a range sheep experiment station of approximately 4,000 acres, similar to the Eastern Colorado Range Station (beef cattle) is clearly indicated. The initial costs of establishing this station would include land aquisition, station headquarters, sheep and lamb handling and weighing facilities and fencing. The annual operating cost would probably be similar to that of the Eastern Colorado Range Station which has a current operating budget of approximately $30,000.

Shrub Infested Range Improvement Studies

Several million acres of rangeland in Colorado are covered with weedy trees, shrubs and herbs, which are of little value for grazing. Sagebrush, oakbrush, pinon pine, junipers, soapweed, yucca, cactus, and rabbit brush are a few of these weedy plants. The studies to date, as mentioned on page V-16 indicate a tremendous gain in grazing values by controlling these plants.

Future studies should include the development of more economic methods of controlling the shrubs, reseeding to improve grasses and legumes, and managing the ranges to prevent a new invasion of the tree and shrub species removed.

Available literature indicates that these plants contain unknown amounts and kinds of oils, resins, turpentine, tannins, soapy substances, fibers, rubber, nutritive materials, etc., which may be useful for agricultural and industrial purposes or in the drug trade. Chemurgic research should be initiated to ascertain usable quantities of such materials and develop efficient uses of such plant materials. The initial phases of such studies might be a systematic chemical survey of the amounts and kinds of potentially useful substances in these plants. About $25,000 annually for a period of at least five years would be required to conduct such a survey based upon present estimates. If quantities of such substances prove sufficient to warrant commericial development, chemical engineering research, possibly including the erection of pilot plants, may be necessary to develop profitable methods of extraction.

Additional Range Improvement Studies

The following needs are clearly indicated:

1. To expand research on the management of Ponderosa Pine-bunchgrass ranges in the front range and the mountain grass and aspen range on the Western Slope.
2. To develop methods of improving and managing game habitat throughout the area.
3. To provide a satisfactory basis for balancing livestock grazing, game grazing, water production and timber production on lands where two or more of these uses are important.
4. To appraise and learn how to control range pests. These are primarily rodents but insect and disease problems should be evaluated.
5. To improve techniques of seeding depleted ranges to new grasses, legumes and shrubs.
6. To control poisonous plants and manage livestock on infested ranges to minimize loss.
7. To integrate ranges improved by proved methods with the management of native ranges.

Mountain Meadow Improvement Studies

Research should be continued to determine: (1) soil relationships; (2) most productive grass and legume species; (3) optimum amounts, methods and times of application of irrigation water; (4) nutritional value of forage; (5) effects and economics of fertilization, drainage; and (6) effect of livestock utilization by pasturing, contrasted to utilization of the area for winter hay production.

Current studies should be expanded to other areas with varied soil types, climate and water supply.

Water Production, Use, and Development Studies

Improvement of farm and rangeland may, in itself, assure better quantity and quality of water. But considerable information is still needed on (1) irrigation practices; (2) consolidation of existing ditches and canals; (3) reducing water loss from storage and distribution systems; (4) return flow amounts and value; (5) underground storage; (6) development of upstream storage to slow runoff and assure late season water supply; (7) costs and benefits of water; (8) resolving conflicts between users and types of use; (9) influence of rodents and other animals on the watershed; and (10) control of low value "water-loving" plants.

Educational Needs

People of all ages, in all walks of life, rural and urban, need to become more fully aware of our mountain range resource, its value, its potential, and its uses and their responsibility, individually and collectively, to preserve and improve that resource for the best balance of continued benefit. To this end, educational efforts should be intensified.

Range management education, making full use of all the knowledge and tools available, is needed in every county. To succeed such efforts must take into consideration the know-how and experience of successful ranch operators and must be fully understood and then applied by operators. Additional personnel, trained in organization as well as in technical matters, will undoubtedly be needed to make this a reality. Provision for an Extension Range Management

Specialist at Colorado State University would fill a considerable portion of this need. Additional county extension personnel, trained in range management, would be valuable in some key range counties.

Youth group programs and conservation education in schools should be expanded to include range conservation and to reach all youth. To meet this need, more undergraduate and postgraduate conservation courses should be offered by the state's teacher training institutions and the program of conservation training workshops for teachers must be accelerated.

Cooperative demonstrations on grazing management and range allotment improvement should be expanded both in number and scope. Broader illustration of watershed and recreation values in addition to forage and livestock benefits would enhance the overall worth of the demonstrations, reach a great many additional people, and aid in resolving conflicts.

Incentive and Regulative Needs

Many states recognize the responsibility of the general public to encourage wise beneficial use and improvement of natural resources through incentive or regulatory programs. Examples that merit consideration are:

1. Reduced taxation on privately-owned rangelands when grazing is eliminated to promote revegetation either naturally or following reseeding and a realistic tax scale on grazing lands based on the potential production of that land.
2. Recognition, through financial participation, of the downstream benefits from improvements of the quality and quantity of water from private land in the watersheds.

3. State appropriations to aid Soil Conservation Districts in their program to use every acre of land according to its needs. Thirty-four states currently make appropriations for the direct assistance of Soil Conservation Districts separate from the expense of administration of the States Soil Conservation Act by the state soil conservation board or committee. The amounts vary from $750.00 to $800,000.00 annually, but the average for the 22 states making substantial appropriations for this purpose is $154,655.00 annually. These funds are made available to Soil Conservation Districts for:

a. Travel and expenses for members of district governing bodies while on official duties.

b. Clerical, space, printing, mailing and other office expense.

c. Acquiring, operating and maintaining equipment.

d. Part or full time manager for the District governing body.

e. Planting materials for use on critical areas.

f. Workers to help landowners and operators with application and maintenance of conservation practices and land use.

4. Provision for water resource development in areas and under situations where present federal projects cannot be utilized.

5. Allocation of a portion of the funds received from the lease of state lands for fire and pest protection and for land treatment and structural improvements on those lands.

6. State installation of additional recreational facilities

and improvement of existing facilities, with attention to the multiple use potentials of land and water.

7. A mineral resource development program that reduces erosion hazards and conserves the surface resources of water, forage, and timber.

8. A state act (similar to the Colorado Wind Erosion Act) to provide a means for protecting the public health and welfare from the effects of destructive land use.

FORESTRY

Colorado's forests occupy approximately 31 percent of the total land area of the state, or 20,834,000 acres. These forested lands, generally located in the western half of the state, extend from the eastern edge of the mountains in central Colorado west to the state line. For the most part they are located between 6,000 and 11,000 feet elevation.

In the eastern plains area of the state, there is very little native tree growth except along stream channels and occasional foothill areas. Forestry in this section is limited to the planting and care of windbreaks and shelterbelts.

While we have 20,834,000 acres of land in the state classed as forested, there are only 8,451,000 acres of commercial forest lands. Of this total, 6,668,000 acres are in federal ownership, 132,000 acres are owned by the state, 38,000 acres are in county and municipal ownership and 1,613,000 acres are owned by private citizens.

Altitude and short growing season coupled with the semi-arid climatic conditions within the state are not conducive to rapid timer growth. Therefore, Colorado is not classed as a major timber producing state.

Colorado's Forests Are Multiple Use Areas

Colorado forest lands are truly areas of many uses, and the uses are dependent upon one another. The manner in which one type of resource is managed has a marked influence on the

manner in which others can be used. Forest management must include consideration of recreation, grazing of livestock and watershed values as well as timber production. Indeed, the principal value, of the forested lands in Colorado is for the water they yield. This is true because of the limited total supply of water throughout Colorado and the western United States.

Watershed

A major portion of precipitation in Colorado is in the form of snow, most of which falls and is accumulated in high forested mountain regions. Proper management and protection of these forested areas determine, to a large extent, the quality and quantity of water available for all uses. When forested areas are properly managed, snow melt in the spring is retarded, peak runoff minimized and stream flow during the year remains rather constant. Loss of tree cover, whether through fire, insects and disease or through poor forest management, results in a reduction of usable water and thus reflects adversely on the overall economy of the state.

Recreation

Each year more than 2,700,000 tourists visit Colorado. This influx occurs because of recreational opportunities in the mountains. Colorado's four-season vacation land offers practically every type of outdoor recreation, including fishing and camping, hiking and mountain-climbing, bug and small game hunting, and winter sports. Visitors to Colorado

bring well over $200 million to the state each year and pay an estimated $3 million in state sales tax. Thus the tourist dollar is "big business". The forests of Colorado play a major role in attracting this kind of business to the state.

Grazing

The forest lands provide annual summer feed in the form of grass and shrubs for hundreds of thousands of cattle and sheep. These animals constitute a large share of the foundation herds on which the major portion of the state's livestock industry is based. Properly managed grazing on forest lands not only returns a greater profit to stockmen but is advantageous from the point of view of recreation and watershed protection. For detailed discussion, see the Mountain Range Livestock Ranching portion of this report.

Timber

The forests of Colorado are composed primarily of coniferous stands of timber. The major species having commercial values are ponderosa pine, lodgepole pine, Engelmann and other spruces, Douglas fir and true firs. These species make up over 92 percent of the total volume of timber cut for all purposes. The remaining volume is made up of broadleaf species (so-called hardwoods), aspen and cottonwood.

The total annual harvest of forest products within the state is 173,700,000 board feet. This timber is used principally for lumber production with minor amounts used for forming, pulp wood, fence posts and telephone poles. Colorado timber is comparatively small and the rough terrain makes the cost of logging rather high. This has discouraged large commercial timber operations. Although there are some operators in Colorado using good equipment and manufacturing a good product, the majority of operators are small, and work on a temporary, portable basis.

The forests of Colorado played a very important part in the early development of the state. However, aspopulation increased and transportation facilities improved, competition increased from forest industries outside the state. This competition has had a marked effect upon the expansion of the forest products industries of Colorado, and, coupled with the difficult topography and the comparatively small-sized timber, points up the complexity of attempting to expand and improve the state's timber industries.

In recent years, increased demand from the building trades and the diminishing timber supplies elsewhere have encouraged some west coast operators to move into Colorado with permanent mills. These producers manufacture high grade products, and the trend points toward an expanded forest products industry for the state. As the population

of the state increases and the demand for wood products also increases, opportunities for the wood-using industries will continue to improve. So if we are to fully develop our timber resources, the search for new uses of wood will need to be continued and expanded.

Because other uses are discussed at length in other parts of this report and in other sections of this series of reports, the balance of this section will be devoted to forestry for lumber.

Forest Background Data

Ownership

The land ownership pattern of forest lands is complex, because of the constant shifting of titles from one owner to another, incompleteness of land surveys, dual ownership of large areas where the surface and the sub-surface titles are separately held, and the interspersed character of public and privately-owned land.

Land Use

The use of these lands presents another extremely complicated situation. Use of the public lands (usually by permit or contract) is carried on in conjunction with use of privately owned lands. Furthermore, the topography, availability of irrigation water and length of growing season dictate to a large extent the use made of the land.

For the most part, private owners are ranchers who have considered timber as a liability rather than an asset. markets have been very limited thereby restricting the

opportunities for income from the sale of timber. Marketing methods commonly used have further proven to be a hinderance. These situations have encouraged ranchers to consider grazing as the most profitable use of their land.

Acreage Inventory

The following table gives the most up-to-date information on the land area by classes of land:

LAND AREA BY MAJOR CLASSES OF LAND

	Acres		Percent	
All Lands		66,510,080		100.00
Farm Land		38,385,234		57.71
Woodland*	2,003,686		3.01	
Forest Lands		20,834,000		31.33
Commercial	8,451,000		12.71	
Non-Commercial	12,383,000		18.62	
Other		9,294,532		13.97

* Included in Forest Lands.

While Colorado has not been classed as one of the important commercial timber producing states, there is a sizeable acreage of land classed as commercial forest land. The following table identifies the commercial land area of the state and also shows the acreage supporting saw timber and other forest classes.

COMMERCIAL FOREST LAND AREA BY STAND-SIZE CLASS

	Acres		Percent	
Commercial Forest Land		8,451,000		100.00
Saw Timber Stands		3,827,000		45.28
Old Growth	2,762,000		32.68	
Young Growth	1,065,000		12.60	
Pole Timber		2,285,000		27.04
Seedlings & Saplings		1,544,000		18.27
Non-Stocked		795,000		9.41

OWNERSHIP-COMMERCIAL FOREST LAND

The commercial forest land in Colorado is under the following ownership:

	Acres		Percent	
Commercial Forest Land		8,451,000		100.00
Federal		6,668,000		78.90
National Forests	6,262,000		74.10	
Bur. of Indian Affairs	26,000		0.31	
Bur. of Land Management	368,000		4.35	
Other	12,000		0.14	
State		132,000		1.56
County & Municipal		38,000		0.45
Private		1,613,000		19.09
Farm	994,000		11.76	
Industry*				
Other	619,000		7.33	

* Included in other (private) to avoid disclosure of ownership.

This complex pattern of ownership requires closely co-ordinated planning in all phases of natural resources development.

Live Saw-Timber Inventory

The management of commercial forest land must be based upon an accurate up-to-date inventory of timber stand, not only by total volume but by species and types of timber. Sound management requires a sustained yield objective and accurate information on site productivity. Harvesting the entire forest crop without regard to the future requirements of ownership is very short-sighted. The best available estimate of the volume of live saw timber in the state on all commercial forest land follows:

NET VOLUME OF LIVE SAW TIMBER ON COMMERCIAL FOREST LAND BY SPECIES

	Volume (M) Board Feet		Percent
All Species		25,394,000	100.00
Softwoods		23,777,000	93.63
Douglas Fir	1,343,000		5.29
Ponderosa Pine	2,963,000		11.67
Englemann Spruce & Other Spruce	12,474,000		49.12
True Firs	2,333,000		9.19
Lodgepole	4,610,000		18.15
Other	54,000		0.21
Hardwoods		1,617,000	6.37
Aspen-Cottonwood	1,563,000		6.16
Other	54,000		0.21

Growing Stock Inventory

Management of these lands on a sustained yield basis requires a thorough inventory of merchantable saw timber in order to plan any sensible marketing program. Furthermore, any such system requires an accumulation of facts

regarding the entire timber stand, not just the amount to be harvested now. The young immature stand is the growing stock for future timber sales and must also be included in the inventory.

Such data on Colorado's forest resources, while incomplete, indicates a growing stock reserve capable of supporting a sustained or perpetual yield type of forest management.

The following table presents the volume of growing, immature timber on commercial forest lands by species.

NET VOLUME OF GROWING STOCK ON COMMERCIAL FOREST LAND

	Volume (Million Cu. Ft.)		Percent
All Species		8,037	100.00
Softwoods		7,470	92.95
Douglas Fir	450	5.59	
Ponderosa Pine	990	12.32	
Englemann Spruce & Other Spruce	3,150	39.19	
True Firs	990	12.32	
Lodgepole Pine	1,890	23.52	
Hardwoods		567	7.05
Aspen-Cottonwood	540	6.72	
Other	27	0.33	

Production and Value

Once the volume or inventory of the forest resource has been obtained, the next step is to determine what the production and value of the products derived may be. The following data is estimated, based on the best information obtainable.

ESTIMATED PRODUCTION & VALUE OF FOREST PRODUCTS - 1955

	Volume	Stumpage Unit	Value Total	Product Unit	Value Total
Saw Logs	200,710 MBF.	$5.20	$1,043,692	$32.00	$6,422,720
Pulpwood	17,998 St'd Cords	2.00	17,998	15.00	269,970
Fuelwood					
Growing Stock	5,500 St'd Cords	0.35	19,250	3.50	19,250
Dead Trees	5,000 " "	0.25	1,250	1.30	6,500
Plant Residues	410 " "	0.50	250	8.30	3,405
Poles	36,000 Pieces	2.00	72,000	5.30	190,800
Mine Timbers	206,000 Cu. Ft.	0.10	20,600	0.50	103,000
Posts					
Growing Stock	170,000 Pieces	0.10	17,000	0.35	59,500
Dead and Cull Trees	20,000 Pieces	0.10	2,000	0.20	4,000
Corral Poles	40,000 Cu. Ft.	0.20	8,000	0.30	12,000
TOTAL			$1,184,670		$7,091,145

Production--Total and by Species

Total lumber production in Colorado is at an all-time high. The best estimate for the year July 1, 1956 through June 30, 1957 is in excess of 200 million board feet. With few exceptions the species used in lumber production in Colorado are softwood, or evergreens grown in our high mountain areas. We grow only aspen in the hardwood species of commercial value. The pattern of lumber production by species has remained rather consistent since 1899, as is evidenced in the following table.

LUMBER PRODUCTION TRENDS TOTAL AND BY SPECIES

Lumber Production	1899	1910	1920	1930	1940	1947	1954
MBF	131,746	121,398	67,847	54,688	79,216	144,966	173,707
Species Distribution (%)							
Softwoods	100.0	97.8	100.0	99.8	100.0	99.9	99.1
Douglas Fir			5.7	3.8	12.6	4.3	2.3	2.0
Lodgepole Pine			7.9	15.6	28.2	23.2	24.4	23.8
Ponderosa Pine		72.0	68.5	54.7	36.7	38.0	37.1	27.2
Englemann Spruce		27.9	17.4	20.3	20.5	32.1	35.2	43.1
True Firs			0.3	5.6	1.7	2.4	0.8	2.6
Other		0.1					0.1	0.4
Hardwoods	00.0	0.2	0.0	0.3	0.0	0.1	0.9
Aspen-Cottonwood			0.2		0.2		0.1	0.7
Other					0.1			0.2
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Sawmills

Sawmills to harvest the crop are an essential part of the forest products industries. For reasons listed earlier small mills of less permanent nature have been the usual type found. Small mills ordinarily do not have the equipment necessary to cut quality products. Such items as railroad ties lend themselves especially well to the small circular type, portable mill. A partial inventory of the sawmills in Colorado indicates there are 269 circular or portable type mills as compared to four mills using large permanent type band saws and two mills using another permanent type gang saw installation. A total of 261 of the 275 sawmills in operation in 1954 produced under 5 million board feet annually; and 14 mills produced more than that amount.

Markets

One of the most critical problems facing the forest products industries and forest land managers in Colorado is the need for additional markets, particularly for small size stems.

In considering the forest products market we normally consider the marketing of lumber for building purposes. But there are many other uses. For example, 39 percent of the total lumber cut in Colorado is used in mill work. Thirty-two percent is used for containers of various sorts.

As such market possibilities expand the forest product, opportunities of private timber land owners become more real. The following table shows the distribution used in manufacture of various products from Colorado lumber.

DISTRIBUTION OF WOOD USED IN MANUFACTURE OF BY-PRODUCTS

1948
(Volume in Thousand Board Feet)

Products	Lumber		Veneer	Bolts	Total	
	Volume	Percent			Volume	Percent
Agricultural Implements	71	.14	12		83	0.14
Car Construction	5,157	10.30	3		5,160	8.69
Caskets	542	1.08			542	0.91
Containers	14,046	28.04	5,532		19,578	32.98
Fixtures	1,383	2.76	571	4	1,958	3.30
Flasks	116	0.23			116	0.20
Flooring	100	0.20			100	0.17
Furniture	1,330	2.66	4		1,334	2.25
Handles	3				3	0.01
Housetrailers	5	0.01			5	0.01
Instruments - musical	9	0.02	6	1	16	0.03
Instruments - scientific	2				2	
Machinery	579	1.16			579	0.96
Matches				2,892	2,892	4.87
Millwork	23,356	46.63	166		23,522	39.62
Pallets	235	0.47			235	0.40
Patterns	230	0.46	5		235	0.40
Refrigerators	9	0.02	2		11	0.02
Boat Building	26	0.05			26	0.02
Signs, Displays & Scenery	430	0.86			430	0.72
Sporting Goods	141	0.28	23	1	165	0.28
Surgical Supplies	37	0.07	1	7	45	0.08
Trunks, Valises	25	0.05	4		29	0.05
Vehicles - motor	1,798	3.59	23		1,821	3.07
Venetian Blinds	104	0.21			104	0.18
Woodenware - Novelties	353	0.70	18		371	0.62
TOTAL	50,087		6,370	2,905	59,362	

1948 Lumber production 149,699 MBF.
1948 Lumber used in manufacture 50,087
Ratio lumber used in manufacture to lumber produced 33.47%.

Residue Use

Historically the United States has been a nation known to be extravagant with her natural resources. This situation certainly has been evident in the forest products industry in Colorado. If it were possible to use all the residue from the primary forest products in Colorado, it would be sufficient to supply needed raw materials for two pulp mills each with a daily capacity of 200 tons. Although it is impossible to recover all the wood residue, improved methods of forest utilization will help achieve a more complete use of these very valuable products.

WOOD RESIDUE FROM PRIMARY FOREST PRODUCTS

1955

Kind Of Product	Volume Of Product	Amount Of Residue By Operation			Volume Residue	Percent Residue
		Logging	Mill	Total	*St'd Cds	By-Products
	Thousand Cubic Feet					
Lumbering	31,311	5,220	17,565	22,785	292,115	98.67
Posts	187	7		7	90	0.03
Fuel Wood	985	39		39	500	0.17
Pulpwood	1,404	56	90	146	1,872	0.63
Mine Timber	206	12		12	154	0.05
Poles	670	94		94	1,205	0.41
Miscellaneous	40	8	1	9	115	0.04
TOTAL	34,803	5,436	17,656	23,092	296,051	100.00

*St'd Cord - 78 cubic feet. 296,000 cords would run 2 - 200 tons daily pulp mills.

Economic Importance of Lumber Manufacturers

Of the 1,602 industries in Colorado 188 are devoted to the manufacture of wood products, exclusive of the

furniture business. These establishments employ 2,282 individuals and pay an annual salary of $5,020,000 or 3.48 percent of the salaries for all industries in Colorado. Although manufacture of forest products currently occupies a place of minor importance in the total industrial structure, growth potential is good.

Fires

Fire is a constant threat to Colorado's forests. Each year they consume a large amount of standing timber and cause immeasureable damage to the watershed. Except for those caused by lightning, all forest fires are man-caused. In 1956, a total of 7,196 acres of forest land were burned resulting in damage of $77,436. These damages are timber losses and other losses of a tangible nature. It is extremely difficult if not impossible to determine the extent of the associated damages such as removal of the protective cover of the soil, reduction of soil fertility and damage to forest reproduction.

Although Colorado is not situated in an area of extreme fire danger compared to the west coast, still the increased number of visitors to the forested areas each year increases the fire danger.

The following table shows the causes of fires, area burned and damages for the six-year period, 1951 through 1956.

CAUSES OF FIRES, AREA BURNED AND DAMAGE

(State and Private Lands)

	1951	1952	1953	1954	1955	Average 1951-55	1956
Total Fires:	156	262	212	213	282	225	309
Class A*	42	92	80	71	117	80	123
Class B*	72	131	107	103	130	109	148
Class C*	42	39	25	39	35	36	38
Causes:							
Lightning	27	46	24	33	41	34	52
Railroad	14	30	9	4	41	20	23
Camping	18	42	27	32	36	31	37
Smoker	15	15	15	23	28	19	26
Debris Burning	27	66	43	50	65	50	68
Incendiary	0	3	11	3	1	4	10
Lumbering	4	6	7	5	4	5	4
Miscellaneous	51	54	76	63	66	62	89
Area Burned	11,495	8,564	4,611	4,060	3,601	6,466	70,276
Dollar Damage	$92,867	$69,704	$118,110	$44,639	$26,059	$7,196	$77,436

* Class A - To 1 Acre; Class B - 1 - 10 Acres; Class C - 10 and Over.

Insects

Forest insects are a constant menace and occasionally reach epidemic proportions. When epidemics occur, it is necessary to organize campaign-type control operations. The Forest Insect Laboratory located on the campus of Colorado State University keeps a constant check on the situation.

Control is an extremely expensive operation, since a large part of the work is a ground operation and requires treatment of each individual tree attacked.

The Englemann Spruce Beetle outbreak in the White River National Forest area of Colorado focused national attention on the need for insect control. For the period 1950 through 1956 a total of $5 million in federal funds was spent to control this pest. This amounted to an average annual expenditure of $714,000. During the same period $1 million (annual average of $143,000) in federal funds were spent for the control of the Black Hills beetle and other insects. The State of Colorado appropriated an average of about $3,000 annually for control of forest insects. Expenditure of state appropriated money was confined to state and privately owned lands.

Loss from the Englemann Spruce Beetle infestation was tremendous. On the White River National Forest alone, between 1940 and 1952, approximately 4.5 billion board feet of timber were killed. On the Uncompahgre and San Juan

National Forests in southwestern Colorado (1953 to 1955) over 110 million board feet were killed. It is possible to salvage some of this insect-killed timber. But salvage operations are expensive and the potential use of the wood is limited. The following table shows forest insect infestation, based on aerial surveys in Colorado for 1956.

INSECT INFESTATION IN COLORADO, 1956

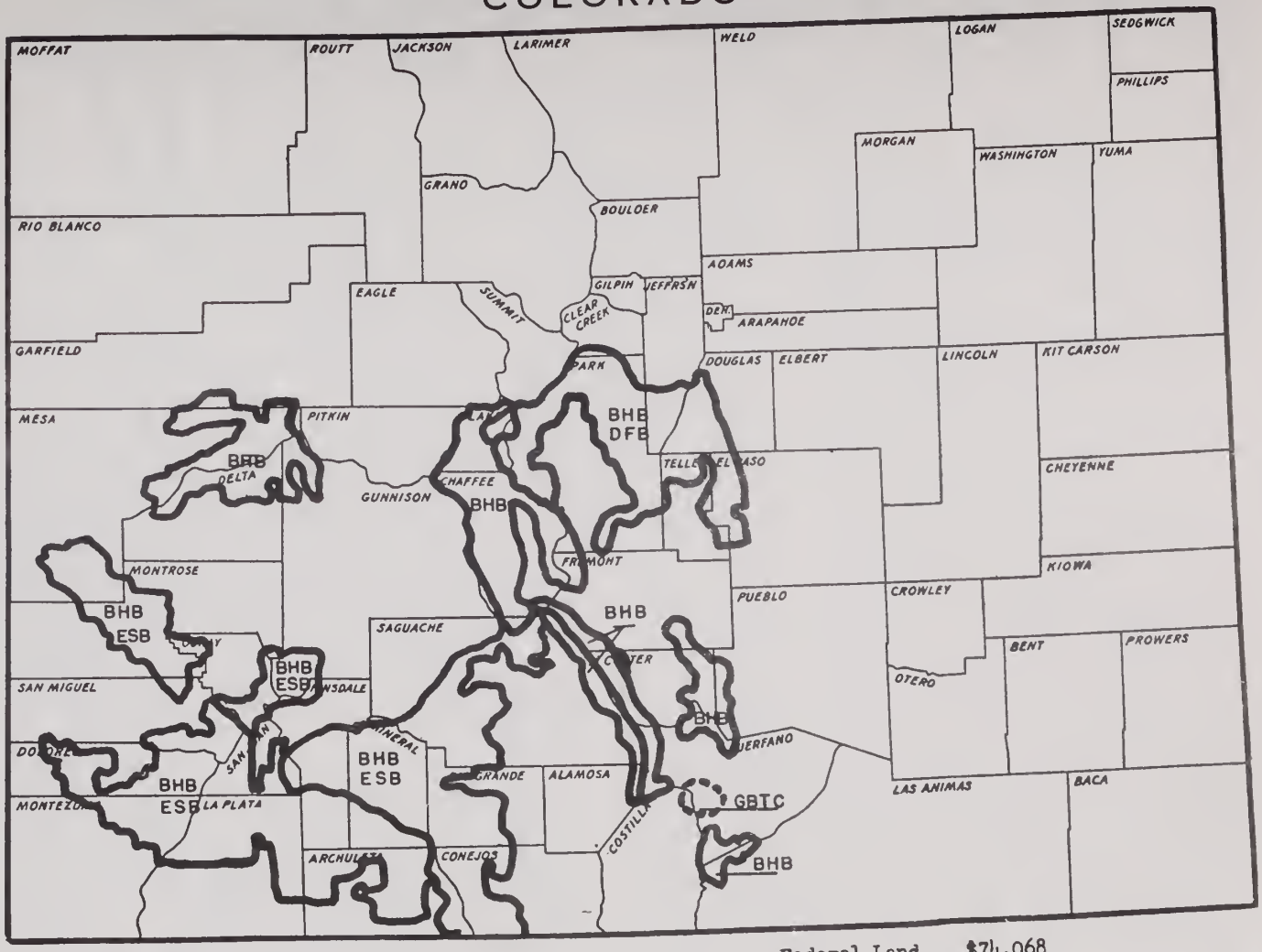
Defoliators	No. Of Centers	Acres of Infestation				
		Light	Moderate	Heavy	Very Heavy	Total
Spruce Budworm	35	20,275	16,281	2,867		39,423
Great Basin Tent Caterpillar	46	12,076	42,598	42,591		97,271
Bark Beetles*						
Englemann Spruce Beetle	18	2,092	1,280			4,372
True Fir Beetle	544	68,912	58,061	6,952	921	134,846
Black Hills Beetle	163	28,057	8,918	3,429	20	40,424
Douglas Fir Beetle	186	13,414	25,598	5,527	512	45,051

*Bark Beetle Categories (Trees killed per square mile)

Light - 20 to 50
Moderate - 50 to 150
Heavy - 150 to 300
V. Heavy - over 300

Based on these aerial surveys estimates were made on needed control measures for the 1957 season. The following map shows the location of forest insect infestations together with an estimate on funds required for control.

COLORADO



BHB Black Hills Beetle
DFB Douglas Fir Beetle
ESB Engelmann Spruce Beetle
GBTC Great Basin Tent Caterpillar

Federal Land	$74,068
State Land	3,500
Private Land	10,104
TOTAL ESTIMATED COST	$87,672

Plains Forestry

Twenty-seven percent of the land area of Colorado is located between the eastern edge of the mountains and the Colorado-Kansas line. With the exception of the Platte River Valley in northeastern Colorado and the Arkansas River Valley in southeastern Colorado, no supplemental water for irrigation exists in appreciable quantities. The remainder constitutes the high plains region of the state. In this area dryland farming and ranching is practiced.

The eastern Colorado plains are treeless, except along the main stream channels and occasional low areas where some subsoil moisture exists. Growing conditions are severedue to the small amount of annual precipitation and the high summer temperatures.

Absence of trees, especially around farmsteads, handicaps livability and appearance. For approximately 40 years limited efforts have been made to establish tree windbreaks and shelterbelts around farmsteads, including barns and corrals, and to a more limited extent, around fields. Many successful plantings have been made. These not only add to the appearance of the farm, but reduce wind velocities, provide needed protection from the sun in summer, and from wind and snow in the winter.

Colorado Forestry Program

Colorado was one of the first western states to recognize the importance of protecting her forest resources. The state constitution, adopted on March 14, 1876, provides: "Article XVII, Section 6, Preservation of Forests - The general assembly shall enact laws in order to prevent the destruction of, and to keep in good preservation, the forests upon the lands of the state, or upon lands of the public domain, the control of which shall be conferred by congress upon the state." This action was the beginning of forest protection in Colorado, and resulted in establishment of some of the first forest reserves, later known as national forests, created in the United States.

In 1910, the General Assembly of the State of Colorado enacted a law creating the office of the state forester, who was to be the professor of forestry at the Colorado Agricultural College. The state's forestry laws were revised in 1911. Responsibility for the control of forest and range fires on public and private lands was assigned to county sheriffs. Organization meetings were held in 42 counties containing timber lands, and 392 deputy sheriffs were appointed to carry out the provisions of the act.

In 1935, a member of the forestry department of the college was asked to assume the State Forester's responsibilities on a part-time basis along with teaching responsibilities. In 1937, the position of Extension Forester was assigned to the state forester. In the same year, the General Assembly established the State Board of Forestry and assigned the added responsibilities

to the State Board of Land Commissioners. This arrangement continued until 1945, at which time a full-time position of State Forester was established. On June 30, 1955, the General Assembly transferred the responsibilities of the State Board of Forestry and the office of State Forester to the State Board of Agriculture. Thus the present Colorado State Forest Service was created.

As is evidenced by this brief historic sketch, the State Forestry Program in Colorado has had a varied and restricted existence. The need for an effective program, recognized by provisions of the state's constitution, has never been implemented sufficiently to permit establishment of a sound, productive program.

The principal purpose of the Assembly in its assignment of the program to the State Board of Agriculture was to cooperate with existing agencies.

In order to cooperate, a basis of common understanding and acquaintance between the cooperating parties must be established. As a means of doing the most efficient job possible with the resources available, the forested area was divided into four districts and a forester employed for each district. To date, the major portion of the district forester's time has been devoted to developing an effective forest fire prevention and control program in each county in his district.

Fire Control and Prevention

Of the more than 20 million acres classed as forest land in Colorado, less than 7.5 million acres are in state and private ownership. As noted earlier, the protection of these lands is the responsibility of 43 county sheriffs, and to a lesser extent,

the State of Colorado. The Colorado State Forest Service is charged with the duty of assisting the county sheriff in carrying out his fire control responsibilities. In this regard, the state organization has negotiated cooperative agreements with the counties in which forest lands exist. Through these agreements, counties are receiving assistance in the preparation and execution of county forest fire prevention and control plans, training paid and volunteer cooperators, acquisition of suitable fire tools, establishing cooperative programs with federal agencies such as U. S. Forest Service and the Bureau of Land Management and some financial aid.

Another means of attempting to develop an effective forest fire prevention and control program is a cooperative agreement between the Colorado State Forest Service and the United States Forest Service. This provides for federal aid in the prevention and control of forest fires and amounts to a refund of $30,000 annually to the state. By the agreement the state and cooperating agencies must spend money for forest fire prevention and control in order to qualify for the federal aid. The Colorado State Forest Service allocates to the counties about two-thirds of the federal fund according to each county's expenditures.

The Colorado State Forest Service has also negotiated cooperative fire control and prevention agreements with the State Highway Patrol, the State Game & Fish Department, and the State Board of Land Commissioners. These departments assist in the detection and suppression of forest fires. In return, the State Forest Service provides them with fire equipment.

Forest Management and Marketing

The management of the forest resource, together with an expanded forest utilization program can serve as a basis for expanded industrial development in Colorado. In order for the forest to support an expanded industry, it is essential that improvements be made in methods employed to manage the timber resource. Improved management will not only result in an improved product available for manufacture but will also result in sustained yield and increased income opportunities for land owners.

Timber owners now receive limited management and marketing assistance from the State Forest Service. This consists primarily of help in determining the amount of merchantable timber, preparation of timber sale contracts to determine the system to be used in harvesting and marketing, and the selection of timber to be sold.

Control of Insects

Each year until 1957, the General Assembly appropriated about $3,000 to be used by the State Forest Service for control of forest insects on state and privately owned forest lands. No money was appropriated for this purpose for the 1958 fiscal year. In a normal year, limited facilities considered, this phase of the program must be carried on with as much outside help as possible. The U. S. Forest Service cooperates through provisions of the federal Forest Pest Act, and pays up to 25 percent of the cost of control on state and privately-owned lands. The State Forest Service, with federal help, attempts to provide chemicals and

necessary equipment to apply them, and negotiates with landowners to provide necessary labor.

Survey work in cooperation with the forest insect laboratory is carried as a part of the routine duties. This is an effort to keep currently informed and to utilize available facilities to the best advantage.

Colorado State Forest Service Nursery

In September, 1956, negotiations between the State Board of Agriculture and the U. S. Forest Service were completed for federal funds to be used to establish a state seedling tree nursery. Funds made available through the Soil Bank program were advanced to initiate the program.

The actual nursery planting began in April, 1957, and will be completed by the spring of 1958. The capacity of the nursery will be two million evergreen seedling trees annually. Production will be limited to evergreen seedlings because they are difficult to produce and, for that reason, are in short supply.

Trees produced in this nursery will be used for farm windbreak, shelterbelt and reforestation planting under provisions of the Soil Bank program. They cannot be resold as living trees and they cannot be used for ornamental purposes. Annual demand for trees heretofore has been about 500,000 --a little less than half of which are for evergreens.

Nursery facilities will also provide refrigerated storage and packing space. This type of installation will make it possible to keep the trees in excellent condition for shipment, and also provide badly needed packing space and equipment.

Since no such program exists in New Mexico, the Colorado State Forest Service provides the service to both states. To date all broadleaved species are obtained from commercial nurseries at wholesale prices.

This program is being financed entirely from the federal aid, which amounts to $1,500 to $3,500 annually, plus the receipts from the sale of trees. No state appropriated money has ever been made available for this program.

Under provisions of the conservation reserve phase of the Soil Bank program, tree planting is one of several recommended practices to be applied to the land. This practice is recognized as being effective in reducing wind velocity and soil blowing as well as helping to stabilize soil and control gullies.

Plains Forestry-- Technical Assistance

Another aid to the states, provided by the Soil Bank program, is funds for the employment of foresters to assist farmers and ranchers with tree problems. Technical assistance in planning, selection and planting trees and shrubs, and general care of the windbreak or shelterbelt quite often determines whether the project will succeed or fail.

The Colorado State Forest Service is cooperating and has employed one forester to work with Colorado farmers and ranchers. He will devote all his time to eastern Colorado.

Problems and Legislative Recommendations

As evidenced by the foregoing portion of this report, forests have long been recognized as an important segment of the state's

supply of natural resources. Yet this recognition has not resulted in sufficient action to permit more than bare minimum facilities for protection, use guidance, and development.

Legislation

Problems are largely the result of vague and inadequate legislation. The state forestry laws are lacking in the definition of terms, in clarity of purpose, and in a clear definition of responsibilities. There is urgent need for modernizing these statutes.

Definition of Terms: In order that any program be effective, a basis for development must be provided. Definition of terms must be made to determine the scope of the activity. Such terms as forests, and watershed lands not only have a bearing on the course of action to be taken, but also the manner in which they should be considered in such problems as taxation, systems of management, etc.

Fire Protection Revisions: No revisions have been made in our state forest fire protection statutes since they were enacted in 1911. Revision and clarification of responsibilities in light of present day land uses, values and needs are of extreme importance. At the moment, it is difficult, if not impossible, to obtain a legal opinion regarding responsibilities for forest protection. The state law provides: "It shall be the duty of the sheriff, under-sheriff and deputies, in case of any forest or prairie fire, to assume charge thereof or to assist other governmental authorities in such emergencies; or controlling or extinguishing such fires; or for assisting in so doing, they may call to their aid such person or persons of their county as they may deem necessary".

While the assignment of these duties to the sheriff is rather specific, the aid which he may expect from the county is not clearly defined, as is evidenced by the following portion of the law: "The county commissioners may allow the sheriff $5 a day for such services and the deputies not to exceed $5 a day, and such other expenses necessarily incurred as they may deem just. The board of county commissioners of any county may make such appropriation as they may deem proper for the purpose of controlling fires in their county. And the board of county commissioners are hereby authorized and empowered to levy a special tax on taxable property within their respective counties for the purpose of creating a fund not exceeding $10,000.00 in any one year for the purpose of controlling, preventing or extinguishing fires in their respective counties." As can be readily seen, a county sheriff is given a specific duty to perform, but he has no assurance that he will be provided the tools with which to do his job.

Situations have occurred in Colorado where counties have become involved beyond their financial means in suppressing forest fires. A fire occurred in Larimer County involving federal, state, and private forest land. The U. S. Forest Service assumed full charge of the fire because federal land was involved. The county share of the cost amounted to over $50,000, an amount beyond the means of the county to pay. When the county refused to pay, cooperative relations between the county and U. S. Forest Service were strained. This experience brought demands from counties for a clear cut determination of county responsibility. While it appears (by

state law) that the full responsibility for suppressing this type of fire rests with the county, members of the attorney general's staff as well as county attorneys are not in agreement. A clear cut statement of responsibilities is urgently needed to clarify this complicated problem.

Responsibility of the state for forest fire suppression and control is almost non-existent. This is true even though there are several thousand acres of state-owned lands supporting forest growth. Under present terms of the law, the county is responsible for protecting state-owned lands as well as privately-owned lands. Many counties feel this is an unjust responsibility because they receive no revenue from state-owned lands. Nor do they receive aid from state-appropriated funds. They feel that the job has been imposed upon them, one in which they are not interested or qualified. Many county commissioners as well as county sheriffs have voiced the opinion that the sheriff's principal responsibility is law enforcement. The extra burden of serving as county fire warden is a responsibility in which he is not interested and should be relieved. Counties would like to be relieved of the responsibility.

Other complications exist. Inasmuch as one county is not permitted to spend money in other counties, it is difficult if not impossible to develop cooperative programs through which equipment owned by one county may be used in suppressing fires in another county. In order to combat forest fires effectively, flexibility in the movement of fire suppression equipment is an absolute necessity.

Our state forest fire laws should be clarified from the point of view of recovering suppression costs and damages incurred as a result of forest fires. Present state statutes provide penalties for setting fire to woods and prairie and contain means of punishing those found quilty. There is no provision for recovery of fire-suppressing costs by a private individual, the county, or by the state; nor are there provisions in the law for recovering the damages caused by such fires. The costs of suppression and damages incurred far exceed modest statutory limitations of fines and imprisonment.

As the number of visitors to Colorado increases, the fire hazard increases. Most other western states have laws in effect which permit the state to close certain areas to fires during periods of high risk, and also provide for means of preventing promiscuous brush and debris burning.

In Colorado there is no clear-cut statute which prohibits promiscuous burning of brush and timber. In practically all of the western states, the state forestry agency is authorized to issue burning permits upon request of the landowner. These permits are issued especially during periods of high hazard, as a means of reducing the incidence of uncontrolled fires and the resultant costs of suppressing those fires.

The landowner in most other states is not completely relieved of his responsibility. In almost every state, forest landowners' responsibilities are specifically identified. There is no such clear-cut identification of this responsibility in Colorado.

Another item contained in most other western states' forestry laws, is a recognition of the public value of the forested lands. Most of these states consider uncontrolled forest fires as a public nuisance.

Improvement in the Colorado fire laws is urgently needed as to coordination of effort between counties, state agencies, and federal agencies. The policy of the Bureau of Land Management, for example, requires that agency to conduct forest fire suppression programs in accordance with state law. The absence of an adequate forest fire law in Colorado makes it necessary for this federal agency to depend upon the determinations of the U. S. Department of Justice to guide them.

The Colorado County Commissioners Association has expressed concern and has appointed a committee to study the situation and make recommendations for legislative changes.

Protection from Over-Cutting: The need for legal safeguards to protect privately owned timber lands from permanent damage by over-cutting is urgent. Concern has not only been from the viewpoint of controlling the manner in which the timber is cut on privately owned lands, but also from the point of view of establishing minimum requirements of harvesting in order that the public and private values may be protected. Such measures, although regulatory upon the landowner, would protect the long-term interests of the landowner as well as the public.

Disposal of Slash: Improper disposal of slash after logging often constitutes a serious fire hazard. Proper disposal of this

debris can have a marked effect in reducing the number of forest fires.

Forest Lands Taxation: State statutes provide that where land has been planted to trees, hedges or orchards it shall not be taxed for a limited period of time, as fixed by law. Furthermore, our laws provide that "The increase in value of private lands caused by the planting of timber thereon (other than fruit trees and hedges) shall not, for a period of thirty years from the date of planting, be taken into account in assessing such lands for taxation; such exemption to apply to all lands heretofore or hereafter planted, except as hereafter provided." "In the event that any such timber shall, prior to the expiration of the thirty years, become sufficiently matured to be suitable for economic use, then the increase of value caused by that so maturing shall be taken into account in assessing the land thereafter." In practice, forest lands in Colorado are generally assessed on the basis of rangeland valuation with complete disregard to timber. The increase in timber harvesting activities within recent years, and the increase that may be expected in years to come indicates that some of those lands should be paying more of their share of cost of the protection they require. Forest taxation becomes very involved. Therefore, a very careful study of forest taxation should be made.

Survey Needed: A state-wide survey of the forested lands in Colorado has never been made. Therefore, no accurate data is available for purposes of taxation, management or sale of forest products. Sound planning requires accurate data as a basis for such plans.

Cooperative programs between the state and federal government offer possibilities of obtaining this important information. Approval of the state, together with cooperation toward financing, is the step needed at this time.

Research

Colorado citizens have a real stake in the state's forest resources. Although much of the timber is on federal lands, increased revenues, employment, and industry could result from a fuller, planned use of such resources. Colorado's timber crop is growing three times as fast as it is being used. Research is needed to remedy this currently unhealthy situation, particularly intensive research in forest utilization, forest products, and marketing.

Current Projects

Forestry research problems under investigation by the Forestry and Range Management Section of the Colorado Agricultural Experiment Station include the following:

(1) Effects of shelterbelts on dryland farms in eastern Colorado.

(2) Wood utilization, preservation, seasoning, and technology to induce more efficient use of Colorado's native woods.

(3) Marketing of forest products in Colorado.

(4) Price determining factors and marketing practices for saw timber stumpage of private timberland owners in Colorado.

Since the majority of the timberlands in Colorado are under federal ownership, numerous other forest management, watershed management, and forest disease and insect studies are being conducted at its forest research centers in Colorado by the Rocky Mountain Forest and Range Experiment Station headquartered at CSU.

Recommended Research

Investigations which are needed to point the way to a fuller and more efficient use of forests are as follows:

(1) Tests to develop new uses for small size trees or to find more economic processing methods for manufacturing existing products. Success would permit thinning operations to convert stagnant forests into more vigorous growing stands.

(2) Tests to develop more economic methods of logging timberlands to induce greater use of timber, particularly that on steep slopes and rugged terrain. For example, cable systems of logging such as the Wyssen system need further investigation to avoid erosion induced by ground logging and skidding systems while at the same time economizing on costs to make logging of such lands more profitable.

(3) New or more economic uses for less valuable or "weedy" tree species such as aspen, sub-alpine fir, scrub oaks, cottonwoods, pinon pine and junipers. In addition to testing their usefulness as charcoal excelsior, boxing and crating, novelty furniture, interior trim, and pulp, chemurgic research should be directed at finding wood chemicals, drugs, dyes, tannins, oils, resins, turpentine, and fibres of value in industry. Development of new product

would offer opportunity for an expanded forest industry in Colorado and reduce "weedy" species for greater growth of commercial timber.

(4) Uses of wood waste and residue as mulching material, bedding material, particle board, pressed blocks or briquettes for fuel and other uses, and possible conversion to wood sugar, molasses and yeast. Fuller and more efficient use of wood would thus be possible and industry could be expanded.

(5) Forest management research needs to be intensified to develop cutting and management systems to control the spread of disease and insect infestations. Stand and timber losses from insects and disease now exceed that due to fire.

(6) Fire weather research needs to be intensified to improve forecasts of fire danger. Modern methods of combatting fire with chemical retardants and airplane also deserve further study.

(7) Studies of cutting and thinning systems to improve growth, timber quality, reproduction and, at the same time, promote greater snowpack and stream flow need to be expanded to other major forest types. Most current studies are concentrated in one or two types.

(8) Factors contributing to better natural regeneration of timber stands require greater attention to induce better and quicker stocking of cut-over and fire or insect-killed stands.

(9) Methods of artificially reforesting cut, burned, and insect or disease-killed forests should be intensively studied. Many such stands remain barren of timber for indefinite periods due to the lack of methods of economic seeding or planting such lands.

(10) There is urgent need for long-time studies in forest genetics. The feasibility of selecting superior seed trees and developing superior strains of nursery stock are unexplored. As direct seeding and planting become more common practices under intensive forestry, the possibility of planting superior timber strains becomes more real.

To facilitate this forestry research program at least one experimental forest should be acquired by land exchange, purchase, or by cooperative agreement. This forest should be located reasonably close to the Colorado State University, preferably on the Poudre River drainage. It would be desirable that it contain several important timber types and encompass three or more small watersheds.

Close cooperation with the Rocky Mountain Forest and Range Experiment Station needs to be maintained, particularly for studies in watershed management, insect and disease control, and fire weather research.

APPENDIX

APPENDIX--INTRODUCTION

Land Resource Areas Map (Page VII-2

The land resource areas map for Colorado shown on the next page has three principle subdivisions. These subdivisions and the basis for each are listed below.

1. Physiographic Region: These are broad subdivisions based on the character of the land, topography, and climate, and are useful primarily from a national standpoint. Colorado has three physiographic regions, namely "D", Great Plains; "E", Rocky Mountain; and "J", the Colorado Plateau.

2. Land Resource Areas: Land resource areas are subdivisions of the physiographic regions and are based primarily on climatic variations. However, topography is used in some instances. For example, D1 is in the Great Plains Physiographic Region and includes areas of 13-18 inches. E1 is the main Rocky Mountain system, E2 is the foothills between the plains and mountains, and E3 is the San Luis Valley Area.

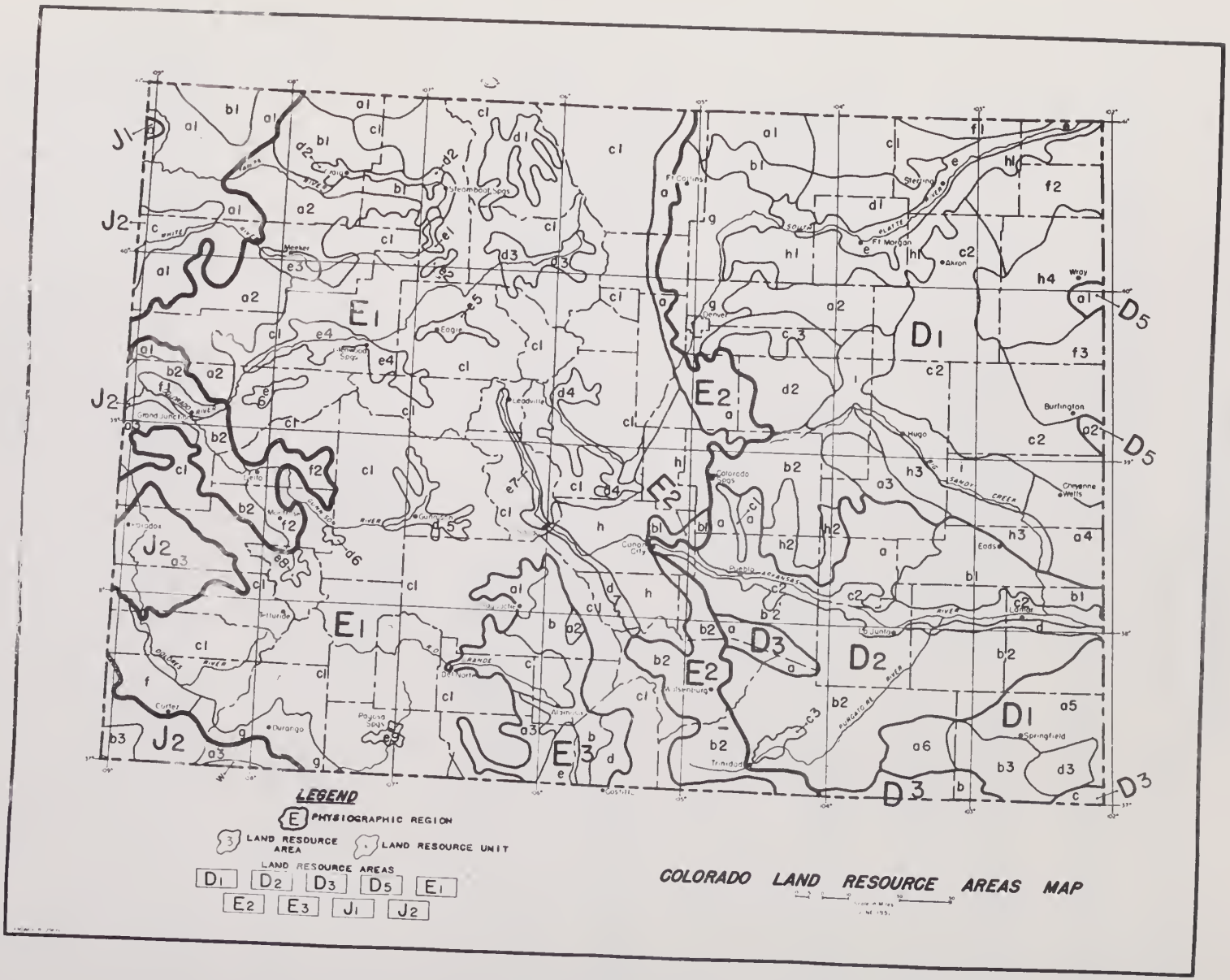
3. Land Resource Units: These are subdivisions within the land resource areas and are based principally on the character of the soil and on climate within the broad groupings above. They are designated on the map as a lower case letter. For example, all sands in the D1 area are indicated by "h2." For reference, all separate areas of "h2 are numbered. We then can have a symbol D1h1, D1h2, as a reference to find the specific areas on the map.

REGION D
RESOURCE AREA D1
Eastern Colorado
Great Plains Dry Sub-humid Dryfarm Area

The various Land Resource Units are described briefly in the legend below.

D1a: Upland hills and valleys of deep hardland soils in a zone of moderately low precipitation. The soils are developed chiefly from loessial and old outwash materials, are dominantly deep and medium to moderately heavy textured. The occasional areas of rough broken lands are composed chiefly of shallow, medium textured, stony or gravelly soils. The landscape consists of gently undulating to rolling hills and valleys with an occasional steeply sloping and rough broken area. Slopes range roughly from 2 to 10 percent. Elevations range from approximately 4,500 to 5,500 feet.

The climate is characterized by short hot summers, long cold winter, moderately low rainfall, and high evaporation. The average annual precipitation ranges from 13 to 15 inches, wide fluctuations occur from year to year. The seasonal distribution of precipitation is extremely erratic.


LEGEND
PHYSIOGRAPHIC REGION
LAND RESOURCE AREA
LAND RESOURCE UNIT
LAND RESOURCE AREAS
D1 D2 D3 D5 E1
E2 E3 J1 J2
COLORADO LAND RESOURCE AREAS MAP

Native vegetation consists chiefly of blue grama, buffalo, and other short grasses.

Maximum land capability under dry land conditions is Class IV. Dry farming is a hazardous operation because of limited rainfall. Both wind and water erosion are active, with wind erosion being dominant. Moderate to severe wind erosion is common on the dry farm lands. Probably best use of the land is for grazing with the more favorable areas, from a soil and topography standpoint, being used for the production of supplemental livestock feed crops.

D1b: Upland hills and valleys of deep sandy land soils in a zone of moderately low precipitation.

The soils are developed mainly from old outwash materials, are dominantly deep, and sandy to moderately sandy in texture. The landscape consists of undulating to gently rolling hills and valleys. Slopes range from 2 to 10 percent. Elevations range from about 4,500 to 6,000 feet.

The climate is characterized by short hot summers, long cold winters, moderately low rainfall, and high evaporation. The average annual precipitation ranges from 13 to 15 inches, wide fluctuations occur from year to year. The seasonal distribution of precipitation is extremely erratic.

Native vegetation consists chiefly of blue grama, sand dropseed and similar grasses adapted to sandy soils.

Maximum land capability under dry land conditions is Class IV. It is generally less difficult to establish cover crops on these sandy soils than on the hardland soils in the same climatic zone because of more efficient use of light rainfall. Dry farm cash crop production, however, is a hazardous operation because of limited rainfall and high susceptibility of these soils to wind erosion. Probably best use of the land is for grazing with the more favorable areas, from a topography standpoint, being used for the production of supplemental feed crops.

D1c: Upland plains and valleys of deep hardland soils in a zone of moderate precipitation.

The soils are developed largely from materials of loessial origin, are dominantly deep and medium to moderately heavy in texture. The topography varies from nearly level and smooth to gently undulating. Slopes vary from 1 to 5 percent. Elevations range from 4,500 to 5,000 feet. The climate is characterized by short hot summers, long cold winters, moderate rainfall and high evaporation. The average annual rainfall varies from 15 to 17 inches. Wide fluctuations occur from year to year. During some years as much as one-fourth

of the rain will come in short torrential downpours, which produce high runoff and erosion.

Erosion varies from slight to moderate. Severe erosion has taken place in localized areas. Wind erosion is the dominant type on the more nearly level dry farm lands and both wind and water erosion have been active on the sloping lands.

Native vegetation consists chiefly of buffalo and grama grasses. Dry land farming, while somewhat hazardous because of limited rainfall, is practicable where soils and topography are favorable. The maximum land capability under dry farming is Class III. This unit comprises a large portion of the most important dry farm lands in eastern Colorado. Wheat, other small grains and sorghums are the principal crops grown. Lands in the eastern portion are used mostly for grazing. Small tracts, particularly of the more rolling lands, interspersed throughout the area, are used for grazing.

D1d: Upland hills and valleys of deep sandy land soils in a zone of moderate precipitation. The soils are developed from old outwash materials, are dominantly deep and sandy to moderately sandy in texture. The landscape consists of undulating to gently rolling plains and valleys. Slopes vary from 2 to 10 percent. Elevations range between 4,500 and 6,000 feet.

The climate is characterized by short hot summers, long cold winters, moderate rainfall and high evaporation. The average annual rainfall varies from 15 to 17 inches. Wide fluctuations occur from year to year.

Erosion varies from moderate to severe with wind erosion being dominant. Native vegetation consists chiefly of blue grama, sand dropseed and similar grasses adapted to sandy soils. The maximum land capability under dry land conditions is Class III. Lands in this unit are generally suitable for cultivation where topography and soils are favorable. Corn, sorghums and small grains are the principal crops grown. Small areas of rangeland are interspersed throughout the area.

D13: Irrigated bottomlands and terraces along the South Platte River valley.

Soils are highly variable as to texture and depth. Declining soil fertility due to leaching from over-irrigation and erosion is a serious problem in this Unit. Other equally important problems are: Seepage from irrigation canals. water-logging of lands due to seepage and overirrigation, and reduction in crop yields due to increasing salt accumulation in the soils.

The topography is nearly level to gently undulating. Slopes range between 1 and 3 percent. Elevations range from 3,500 to 4,500 feet.

Annual precipitation ranges from about 13 inches in the western part of the valley to approximately 17 inches in the extreme eastern portion.

Moderate to severe gully erosion is active in irrigation ditches and on sloping lands in local areas.

D1f: Upland plains and valleys of deep hardlands in a zone of moderately high precipitation.

The soils are developed from materials of mixed loessial and outwash origin. They are dominantly deep and medium to moderately heavy textured.

The topography varies from nearly level to gently undulating. Slopes vary from 1 to 3 percent. Elevations range from 3,500 to 4,500 feet.

Annual precipitation averages 17 to 19 inches. Moderate wind and water erosion has occurred in localized areas.

Native vegetation consists mainly of buffalo grass, blue grama, and (western wheat grass.)

This Unit comprises the balance of the most important dry farm lands in eastern Colorado. The maximum land capability under dry farm conditions is Class II. Dry farming operations are only slightly hazardous. Wheat and other small grains are the principal crops grown.

Rainfall is generally sufficient to produce some leguminous crops, (sweet clover).

D1g: Upland hills of mixed hardlands and moderately sandy lands, dominantly irrigated.

The soils are highly interspersed. The deep soils are developed principally from loessial and old outwash materials, whereas the moderately deep soils are mainly residual on sandstones and sandy shales. The highly variable lands in the alluvial valleys of the South Platte River and its major tributaries comprise an important part of the Unit. Local areas of shallow soils on sandstone and shale are common in the northern portion.

The topography is undulating to gently rolling. Slopes vary from 2 to 10 percent. Elevations range from 5,000 to 5,500 feet.

Annual precipitation varies from 13 to 15 inches.

Native vegetation consists chiefly of blue grama, buffalo

and other short grasses.

Land use on the uplands is an interspersed pattern of irrigation, dry farming and grazing. Irrigation farming is the principal land use in the alluvial valleys. Erosion in general is moderate, with both wind and water erosion being active on the cultivated lands. Erosion is generally slight in the pasture areas.

D1h: Loose sands and sandhills in the Great Plains Dry sub-humid Area.

The soils are mainly deep loose sands and light loamy sands. Soils in the valley-like areas between sandhills usually are slightly heavier in texture.

The landscape is undulating and hummocky to rolling and consists of a succession of dune-like hillocks rising to heights of 10 to 60 feet or more above the depressions. Slopes vary from about 3 to 20 percent. Elevations range from 3,500 tp 5,500 feet.

The average annual precipitation varies from about 13 to 17 inches.

Native vegetation consists chiefly of sand reed grass, sand dropseed, sand sage, yucca and other plants adapted to very sandy soils.

The maximum land capability is Class VI. Lands in this unit are not suitable for cultivation because of the extremely sandy nature of the soils and because of topography. Since the lands in this Unit are non-arable, it is believed unnecessary to separate them into the three established climatic zones in the Area, as was done for the arable lands.

Severe wind erosion has occurred locally where the native vegetation has been depleted and where attempts have been made to cultivate the land. Land use is almost entirely grazing. Dry farm cultivation has been attempted on scattered tracts where the topography is more favorable without much success. Most of the lands which were cultivated have since been abandoned. Some dry farming is being carried on successfully in the more favorable valley-like and depressional areas, where the soils are slightly heavier. Corn is the principal crop grown.

D1i: Heavy clay lands in the Great Plains dry sub-humid resource area.

The soils are developed from clay shales, are shallow to moderately deep and heavy textured.

The topography is undulating to rolling and steeply sloping.

Steep escarpments are common, particularly in the northern portion of the Unit. Slopes range from 2 to more than 20 percent. Elevations range from 5,000 to 6,000 feet.

Average annual precipitation varies from 13 to 15 inches.

Native vegetation consists chiefly of blue grama, buffalo and other short grasses. Scattered pinon and juniper trees are common in the northern and rougher portion of the unit.

Erosion varies from moderate to severe. Water erosion is the dominant type.

The maximum land capability is Class VI. Practically all of the area is used for grazing.

RESOURCE AREA D2
Eastern Colorado
Great Plains Semi-arid Range Area

D2a: Heavy clay lands in the Great Plains semi-arid range area.

The soils are developed from clay shales, are shallow to moderately deep and heavy textured. Shale outcrops are common.

The topography is undulating to rolling. Slopes range from 2 to more than 20 percent. Elevation varies from 4,500 to 5,500 feet.

Average annual precipitation is about 12 inches.

The native vegetation consists chiefly of blue grama and similar grasses adapted to semi-arid climate.

Water erosion is the dominant type. Erosion damage in localized areas has been moderate to severe.

The maximum land capability under dry land conditions is Class VI. Practically all of this area is used for grazing.

D2b: Deep and moderately deep hardlands in the Great Plains semi-arid range area.

The soils are developed chiefly from silty shales, are dominantly shallow to moderately deep and medium to moderately heavy in texture. Rather large areas of medium textured loessial soils are common in the southern portion. Small areas of moderately sandy soils developed from old out-wash materials are scattered throughout the Unit.

The topography is undulating to rolling and slopes range from 2 to more than 10 percent. Elevations range from 4,000 to 5,500 feet.

Precipitation varies from about 11 to 13 inches annually.

Native vegetation consists chiefly of blue grama and other short grasses adapted to a semi-arid climate.

Both wind and water erosion have been active. Erosion is generally slight to moderate. Severe erosion has taken place locally where the native vegetation has been severely depleted and where attempts have been made to cultivate the land.

The maximum land capability is Class VI. The land is used almost entirely for grazing. Dry farming has been attempted on limited areas with little success.

D2c: Irrigated alluvial bottomlands and terraces along the Arkansas River and its major tributaries.

The soils are developed from recent alluvium and are highly variable as to texture and depth.

The topography is nearly level to gently undulating with slopes ranging from 1 to 3 percent. Elevations vary from 3,500 to 5,000 feet.

The average annual precipitation is about 11 inches.

Land use is mainly cultivation under irrigation. Sheet and gully erosion on sloping lands are moderate to severe in local areas.

Declining soil fertility due to leaching through over-irrigation, continuous cropping and erosion is an extremely serious problem in this Unit. Other important problems are silt deposition from irrigation water, losses of irrigation water through seepage from canals, water-logging of lands due to seepage and over-irrigation and reduction in crop yields due to increasing salt accumulation in the soils.

D2d: Loose sands and sandhills in the Great Plains semi-arid range area.

The soils are deep loose sands and light loamy sands.

The topography is gently rolling to dune-like. Slopes range from about 3 to more than 20 percent. Elevations vary from 3,500 to 4,000 feet.

Annual precipitation averages about 11 inches.

Native vegetation consists chiefly of sand reed grass, sand dropseed, sand sage, yucca and other plants adapted to extremely sandy soils.

Wind erosion predominates, with damage ranging from moderate to severe.

The maximum capability is Class VI. All of the area is used for grazing.

RESOURCE AREA D3
Eastern Colorado
Mesas, Canyons and Breaks Area

D3a: Shallow and moderately deep mixed hardlands and sandy lands.

The soils are developed principally from sandstones and limestones, are shallow to moderately deep and medium to moderately light textured.

The landscape is a complex of undulating to gently rolling uplands and narrow valleys. Deep canyons with sharp escarpments are common. Slopes range from about 3 to more than 100 percent. Elevations vary from 5,500 to 6,500 feet.

The average annual precipitation is 13 to 15 inches.

Native vegetation consists chiefly of blue grama and similar grasses with an occasional stand of pinon and juniper, particularly in the rougher portions.

Moderate sheet and gully erosion has taken place locally. The maximum capability is Class VI.

The land is used almost entirely for grazing. A few small tracts are used for the production of small grain under dry farm conditions.

D3b: Shallow to moderately deep soils developed from a wide variety of geologic materials.

The soils are developed chiefly from basalts, sandstones and shales, are shallow to moderately deep, and medium to moderately light textured. Rock outcrops are common.

The topography is rolling to rough broken, deep canyons and sharp escarpments are common. Elevations range from 6,000 to 8,000 feet.

The average annual precipitation varies from 15 to more than 18 inches.

Erosion is generally moderate. Severe sheet and gully erosion has occurred locally in areas where the range has been heavily over-used.

Native vegetation consists chiefly of pinon, and juniper, with an understory and interspersed areas of blue grama, and similar grasses. Scattered patches of oak brush and an occasional yellow pine tree are common in the higher and rougher portions of the Unit.

The maximum land capability is Class VI. The entire area is

used for grazing and woodland.

D3c: Loose sands and sandy soils along the Cimarron River breaks. The topography is undulating and hummocky to rolling and dune-like. Slopes vary from about 3 percent to more than 20 percent.

The average annual precipitation is 15 to 17 inches.

Native vegetation consists chiefly of sand reed grass, sand drop seed, sand sage and other plants adapted to extremely sandy soils. The area is used almost entirely for grazing.

RESOURCE AREA D5
Eastern Colorado

D5a1: Arickaree River Break Area: The topography is hilly to steeply sloping with elevations varying between 4,000 and 4,500 feet.

The average annual precipitation is about 18 inches.

The soils are developed from loessial, tertiary and cretaceous material, are shallow to moderately deep and medium textured.

Native vegetation consists chiefly of buffalo grass and blue grama grass.

Water erosion predominates and is moderate to severe. The land is used for grazing.

D5a2: Has been included in Unit D1c2.

REGION E
RESOURCE AREA E1
(Western Colorado)
Rocky Mountain Area

E1a: Very shallow, shallow and medium depth soils of the rolling to steep areas in the Rocky Mountain Region. The soils are medium textured. They range from very shallow to medium depth on the oak brush land and from medium depth to deep on the sage brush areas and dry farm land.

The topography is rolling to steep with slopes ranging from about 40 to more than 100 percent. Elevations range between 6,000 to 9,000 feet.

Precipitation ranges from 16 to 24 inches.

The native cover is predominantly oak. The high north facing slopes have a cover of aspen, spruce and fir. The south

facing slopes, especially in the White River Valley have a cover of juniper and pinon. Sage cover is common on some of the gently rolling slopes.

Many of the valleys have actively cutting washes. Erosion on the slopes is largely confined to the denuded slopes and areas between oak brush patches.

Most of the area is used for range, however, there are numerous small dry farms scattered throughout the northern and eastern parts.

Elb: Gently rolling to steep areas at elevations between 6,000 and 7,500 feet.

The soils vary in depth from shallow to deep, and are medium to heavy textured.

Precipitation over the area ranges from 16 to 25 inches annually.

Native vegetation is predominantly "little" sage and big sage in the western part of the Unit, and oak brush in the eastern part. Some of the north and east facing slopes have a large amount of choke cherry and service berry. Patches of aspen, spruce or fir occur in the higher elevations on some of the north facing slopes. Many of the sage and choke cherry areas are being farmed. Wherever water is available they are being irrigated. The sage areas are considerably overgrazed and erosion is active. There is moderate erosion on the farm land.

The maximum land capability is Class VI.

Elc: The principal Rocky Mountain System. Includes steep rocky slopes at higher elevations, the mountainous and alpine areas.

Eld: Valley bottoms and adjacent alluvial fans at elevations between 6,200 and 6,900 feet.

The soils are medium depth to deep over gravel. Textures range from light to heavy and are frequently stratified.

The topography is nearly level to gently sloping.

Precipitation ranges from 15 to 24 inches annually.

Irrigated and sub-irrigated hay meadow and pasture is the principal land use. Some areas are being used to produce small grain, alfalfa and truck crops.

Ele1: Yampa Valley at Yampa: Conditions are similar to those in Resource Area Eld described above, except more of the land is used for general farming. Small grain and lettuce are grown in addition to hay and pasture.

Ele2: Toponas Unit: The topography is undulating to gently rolling with elevations varying between 8,000 to 8,500 feet.

The soils are generally medium textured and medium depth to deep over gravel, or gravelly substratum.

Precipitation ranges from 14 to 16 inches annually.

Irrigated and dry land are interspersed with range. Hay, pasture and lettuce are produced on the irrigated land.

Erosion is moderate on range and cultivated land.

The maximum land capability is Class VI.

Ele3: White River Valley and adjacent mesas and alluvial fans: The valley floor is nearly level to undulating. The mesas and fans are gently sloping to gently rolling.

Elevations vary between 6,000 to 6,700 feet.

Precipitation ranges from 14 to 17 inches annually.

The valley soils are medium textured and range from shallow to deep over gravel. The upland soils range from shallow to deep and are medium to moderately heavy textured. The shallow soils on the upland are generally underlain by a gravelly substratum or shale. The breaks are shallow and gravelly or stony.

Native vegetation is predominantly sage, juniper and pinon. Alfalfa, small grain, hay and pasture are produced on the irrigated land and small grain on the dry farm land.

Ele4: Colorado River Valley-Rifle, Glenwood Springs, DeBeque and Grand Valley areas: The topography is undulating to gently sloping, with elevations varying between 5,000 to 7,000 feet.

Precipitation ranges from 10 to 16 inches annually.

The soils are generally medium depth to deep over gravel or gravelly soil material. Soil textures range from medium to heavy. Most of the soils in the Grand Valley and DeBeque areas contain saline and alkali salts in varying amounts. The soils north of the river are derived from Wasatch shales and are generally heavy textured and highly dispersed.

Native vegetation is largely pinon, juniper, sage, shadscale and greasewood. Most of the land is under irrigation.

Erosion on the irrigated land is moderate.

Ele5: Eagle Valley Area: The topography is undulating to gently rolling with elevations varying between 8,000 to 8,500 feet.

The soils are generally medium textured and medium depth or deep over gravel or gravelly substratum.

Precipitation ranges from 14 to 16 inches annually.

Irrigated and dry farm land are interspersed with range. Hay, pasture and lettuce are produced on the irrigated land.

Erosion is moderate on range and cultivated land.

The maximum land capability is Class VI.

Ele6: Collbran Area: The landscape consists of many long fans dissected by canyons.

The topography is gently sloping to rolling. Most of the valleys are narrow.

Elevations vary between 5,000 and 6,500 feet.

Precipitation ranges from 14 to 17 inches annually.

The soils are predominantly medium and moderately heavy textured, and range in depth from very shallow to deep. Gravelly or stony soil material under lies the soils. Most of the stones are basalt and range in size from less than one inch to several feet in diameter.

The native vegetation is mainly sage, pinon and juniper, with some oak. Most of the gentle slopes are irrigated. The steeper slopes and breaks are used for range.

Erosion on most of the irrigated land is moderate.

Ele7: Arkansas River Valley area, north of Salida: The topography is undulating to gently sloping. Elevations vary between 7,000 to 10,000 feet.

Precipitation ranges from 8 to 12 inches annually.

Most of the soils are shallow or very shallow over gravel. Very cobbly, stony or gravelly areas are common.

The native vegetation is short grass. Practically all of the land is irrigated.

Erosion on the irrigated lands is slight to moderate.

Ele8 and Ele9 Uncompaghre Valley, Ridgeway and Pagosa Springs areas: The Ridgeway area consists of one main valley.

The Pagosa Springs area consists of a number of narrow valleys

with rolling lands between.

Elevations range between 6,800 and 7,200 feet.

The precipitation at Ridgeway is about 17 inches annually. In the Pagosa Springs area precipitation ranges from 20 to 23 inches annually.

The soils in both areas are moderately deep to deep over gravel or shale and are predominantly moderately heavy to heavy textured. Some areas of the river bottom soils are light or medium textured.

The valleys and some of the side slopes in the Pagosa Springs area are irrigated. Some of the rolling uplands are dry farmed. The remainder of the Unit is covered with a thin stand of ponderosa pine, with an understory of oak, brush or grass. In the Ridgeway area some of the alluvial fans are irrigated. Native vegetation on the non-irrigated portion is sage, juniper and pinon.

Erosion is moderate to severe on the non-irrigated land and slight to moderate on the irrigated land.

Elf: Rolling lands dissected by canyons and occurring at elevations ranging from 6,200 to 7,500 feet.

The average annual precipitation over this Unit ranges from 14 to 20 inches. The soils are predominantly developed from wind laid materials. Most of the soils are deep and medium textured. Along the breaks the soils are shallow or very shallow. Rock outcrops occur along the breaks.

Native vegetation is sage brush on the rolling land and pinon-juniper along the breaks. Pinon and juniper are invading some of the sage brush areas. Much of this Unit is being dry-farmed.

Erosion activity is moderate.

Elg: Irrigated lands-Mandos-Durango Area: The general landscape consists of narrow valleys, broad alluvial fans, mesas and rolling lands.

Elevations range between 6,000 and 7,000 feet.

The average annual precipitation over the Unit ranges from 14 to 20 inches annually.

The soils are moderately heavy to heavy and range in depth from shallow to deep. The shallow soils are underlain by sandstone, shale gravel or gravelly soil material. Less than one-fourth of the Unit is irrigated. There are a few small

dry farm areas. The remainder of the Unit is covered with sage, pinon, juniper, or oak. The sage and juniper-pinon areas are in poor condition.

Erosion on the crop land is slight to moderate.

E1h: Rolling to steeply sloping mountainous land occurring at elevations ranging from 8,000 to 10,000 feet.

The average annual precipitation over this Unit varies from 15 to 20 inches.

The soils on the slopes and in the valleys are derived largely from granite, are moderately deep to deep and medium textured. Most of the soils are gravelly. The soils on the hills and mountains are shallow to very shallow and stony or gravelly.

The hills have a cover of yellow pine. Some of the higher north facing slopes have a cover of aspen, spruce and fir. The valleys are open grassland. Most of the land is used for range.

Erosion is moderate to severe.

RESOURCE AREA E2
Eastern Colorado
Rocky Mountain Foothills

E2a: Foothills and rough broken lands along east front of the Rocky Mountains in northern part of the Foothills-Resource Area-sub-humid to humid climatic zone.

The landscape is a complex of rolling and rough broken hills and valleys with slopes ranging from about 5 to more than 50 percent.

Elevations vary between 6,000 and 8,000 feet.

The average annual precipitation is approximately 17 inches.

The soils are developed from a wide variety of igneous and sedimentary rocks. They are shallow to moderately deep and moderately light to medium textured. In most places varying amounts of stones and gravel are present.

Native vegetation consists chiefly of mountain mahogany, oak brush, choke-cherry and other mountain brush types. Western wheat and similar grasses cover interspersed areas. Scattered stands of yellow pine occur on north slopes in the rougher portions of the Unit. Practically all of the land is used for grazing. Small tracts along permanent streams are used for meadow hay. Small tracts in the southern part of the Unit where the topography is more favorable are used for dry-farming.

Moderate to severe sheet and gully erosion has occurred locally on the dry farmed land.

E2b: Foothills and rough broken lands along east front of Rocky Mountains in southern part of the Foothills Resource Area-semi-arid to sub-humid climatic zone. The landscape is a complex of rolling and rough broken hills and valleys with slopes ranging from about 5 to more than 50 percent.

Elevations vary between 5,500 and 6,500 feet.

The average annual precipitation is about 15 inches.

The soils are developed from a wide variety of igneous and sedimentary rocks. They are shallow to moderately deep and moderately light to medium textured.

In most places varying amounts of stones and gravel are present.

Native vegetation consists chiefly of pinon and juniper. Blue grama and similar grasses cover interspersed areas. Scattered patches of oak brush and an occasional yellow pine tree are common in the higher and rougher portions of the Unit, particularly on north slopes. Practically all of the land is range and woodland. Small areas along permanent streams are irrigated.

Severe sheet and gully erosion has taken place locally in areas where the range has been heavily overgrazed. Moderate to severe wind erosion has taken place on the dry farm areas.

RESOURCE AREA E3
South-central Colorado
San Luis Valley Area

E3a: Foothills area: The landscape consists of gently undulating to steeply sloping hills and narrow valleys with slopes ranging from 5 to more than 50 percent.

Elevations over the area vary between 7,800 and 8,500 feet. The average annual precipitation varies from 11 to 13 inches.

The soils are developed from outwash materials of mixed igneous and sedimentary origin, are shallow to moderately deep and usually stony.

Native vegetation is mostly blue grama and similar grasses along with pinon-juniper. The land is used for grazing.

E3b: Desert Shrub Valley area: The topography is nearly level to gently undulating with slopes ranging from 1 to 3 percent. Elevations over the valley vary between 7,500 and 7,800 feet.

Average annual percipitation is about 9 inches.

The soils are developed from old valley fill largely mixed sands and gravels. They are sandy to medium textured, dominantly shallow to moderately deep and highly saline.

Native vegetation consists chiefly of greasewood with interspersed areas of salt grass and rabbit brush. Land use is limited to grazing with some large areas not being used at all.

E3c: Sub-irrigated Area--Cultivated: The topography is nearly level to gently undulating with slopes varying from 0.5 to 1.5 percent.

Elevations range between 7,500 and 7,700 feet.

Precipitation averages less than 10 inches annually.

The soils are developed from mixed sands, gravels and cobbles, are shallow to moderately deep, sandy to medium textured, usually gravelly or stony and saline.

E3d: Sagebrush Area: The topography is smooth to gently rolling with slopes ranging from 2 to 10 percent.

Elevations range between 7,500 and 8,500 feet.

Precipitation averages less than 12 inches annually.

The soils are developed from mixed outwash materials, are shallow to moderately deep, sandy to medium textured and usually gravelly or stony.

Native vegetation is chiefly sage brush, blue grama and other bunch grasses. Land use is dominantly grazing. Small areas are irrigated.

E3e: Open Grassland Area: The topography is gently rolling to rolling with numerous steep slopes and escarpments. Slopes range from 5 to more than 50 percent.

Elevations over the area vary from 7,500 to 8,000 feet.

Precipitation averages about 10 inches annually.

The soils are developed from igneous and sedimentary materials, are shallow to moderately deep, sandy to medium textured and highly calcareous.

Native vegetation consists chiefly of blue grama and similar grasses.

Land use is dominantly grazing. Small areas of favorable topography and soils are irrigated.

REGION J
RESOURCE AREA J2
Western Colorado
Mesas, Canyons, Valleys and Plains

J2a1: Northwestern Colorado: The landscape consists of mesa tops, breaks, escarpments and vertical-walled canyons.

Elevations range between 6,000 to more than 9,000 feet.

Precipitation over the area varies from 10 to 16 inches annually.

The valley soils are deep and medium textured. The mesa soils vary from shallow to deep and are largely medium textured. Very shallow soils and rock outcrops characterize the breaks and escarpments.

Native vegetation is predominantly juniper-pinon, with some sage cover on the mesa tops and in the valleys. The land is used for grazing.

J2a3: Central and Southwestern Colorado: Similar in all respects to J2a1 described above, exception elevations, which range from 5,000 to 8,000 feet. This area includes Mesa Verde National Park.

Grazing has been prohibited in the Park since 1957. This has pretty well stabilized erosion in this part of the area. Present activity of erosion in the Park is slight with a few areas of moderate erosion. In the remainder of the Unit the erosion is moderate and severe.

J2b1: Northwestern Colorado: The topography is gently sloping to rolling with elevations ranging between 6,500 to 7,000 feet.

Precipitation over the area varies from 8 to 10 inches annually.

The soils are derived principally from Greenriver and Wasatch shale, are shallow to deep and moderately heavy.

Native vegetation is mostly shadscale and greasewood. The land is used for grazing. Erosion is moderate to severe.

J2c: Rangely Area: The landscape is a complex of the White River Valley, rolling hills, escarpments and canyons.

Elevations over the area range between 5,000 to 8,500 feet.

The average annual precipitation throughout the area varies from 10 to 20 inches.

The soils are predominantly moderately heavy and range from deep in the valleys, moderately deep on the slopes and rolling hills to shallow and very shallow with many rock outcrops on the breaks and escarpments.

Native cover consists of shadscale and greasewood in the valleys, sagebrush on the rolling hills and juniper-pinon on the breaks and escarpments. The land is used for grazing. Water erosion is moderate to severe.

J2f1: Grand Junction Area-Irrigated Valley: The topography is nearly level to gently rolling, with elevations ranging from 4,400 to 4,800 feet.

The average annual precipitation over the valley varies from 8 to 10 inches.

Native vegetation is largely shadscale and greasewood. The soil range from very light to heavy textured.

Soil depths range from very shallow to very deep. The shallow soils are underlain by gravel, gravelly soil material or shale. About one-third of the area is occupied by soils affected by accumulations of salts, alkali, or both. Most of the land is under irrigation.

Erosion is moderate to severe; most of the washes are channelized and are quite deeply entrenched.

J2f2: Delta-Montrose Area-Irrigated Land: Conditions are similar in all respects to J2f1 described above, except elevations range from 4,900 to 5,800 feet, and precipitation varies from 9 to 12 inches annually.

Native vegetation around Hotchkiss and Cedaridge is sage and pinon-juniper.

Current Soil Survey Program (Page I-38)

The following soil survey programs are now in progress or planned in the near future and will supplement current data:

Soil Conservation Service

Standard soil surveys are underway in the following counties:

Prowers	Alamosa	Sedgwick
Morgan	Gunnison	Jackson
Arapahoe	Delta	Boulder
Adams	Crowley	

Other government programs that require soil surveys to be made by the Soil Conservations Service are Farmers Home Administration, Soil Bank, Great Plains, Program and Conservation Needs. These require individual farm surveys, rather than block surveys.

Bureau of Reclamation

Region 7-Eastern slope of Colorado

The Narrows Survey (Platte Valley) has been completed. The report is being prepared.

The Arkansas Valley Survey has been revised; partially detailed map and the new report is being prepared.

Region 4-Western slope of Colorado, Colorado River drainage area.

Silt Project: This is a participating project of the Colorado River Storage Project located on the north side of the Colorado River upstream from Rifle. It has been authorized by the Congress and is now in the advance planning stage which will culminate in the preparation of a definite plan report and secretarial certification of the land classification. A semi-detailed classification was made in 1948 and was adequate for authorization. A detailed land classification was started in the spring of 1957, and completed in July. The irrigable area will include about 5,400 acres presently irrigated and 1,900 acres of non-irrigated land.

West Divide Project: This project includes the bench lands south of the Colorado River in the vicinity of Rifle but actually extending from New Castle to DeBeque. This is not a participating project but is one of the projects given priority of completion in the planning report of the Colorado River Storage Project Act. A detailed land classification is scheduled for initiation early in the summer of 1957 and will require two field seasons to complete. The project will include about 25,000 acres of presently irrigated land to receive supplemental water and 40,000 acres of new land.

Pine River Extension Project. This is an extension of the existing Pine River Project near Bayfield, Colorado. It is a participating project and was authorized by Public Law 485. A detailed classification is now in progress and is about 25 percent finished. The extension will serve about 15,000 acres of new land. The classification will be completed by early summer.

Florida Project. This project is a participating project authorized by Public Law 485. A detailed classification, started last July, is now about 20 percent complete and will be finished by early summer. The project will supply supple-

mental water to 12,600 acres of presently irrigated land and to 6,300 acres of new land just east of Durango.

Dolores Project. This is not a participating project, but is a "Priority" project pecified in Public Law 485. It will supply supplemental water to about 30,500 acres of presently irrigated land near Cortez and to about 35,500 acres of dry land mostly near Dove Creek. The detailed land classification is underway and is about 40 percent finished.

Smith Fork Project. Land classification surveys have been completed and the report will be completed during 1957.

Colbran Project. Land classification surveys have been completed and the report will be completed during 1957.

Paonia Project. Land classification surveys have been completed and the report will be completed during 1957.

Forest Service

Trout Creek Area. Forest Service land in Chaffee and Park counties in the vicinity of Trout Creek Pass. Acreage is not known. Mapping will be completed in 1957.

Boulder Area (Left Hand Creek). This is a small area. Mapping will be completed but publishing is not contemplated.

Black Mesa Experimental Area. Gunnison County--correlation to be completed.

Fraser Experimental Area and Alpine Area, Summit and Grand counties. May be published in 1957.

Colorado River Storage Project, USDA Field Party

Silt Project, 7,300 acres. Report due January, 1958.

Smith Fork Project, 10,400 acres. Project due June, 1957.

Pine River Extension, 15,000 acres. Report due March, 1958.

Florida Project, 18,900 acres. Report due March, 1958.

These project areas will require a representative sample survey. The actual percentage of each area to be surveyed will be determined by inspection of the areas by the field party. It was pointed out that the acreage reported included both presently irrigated and new irrigated land. With the non-arable land, the size of the area to be surveyed will be more than twice the acreage reported above.

The 1957 activities reviewed above are a part of the long-range soil survey program initiated by the Soil Conservation Service in 1956 to obtain complete coverage of the state.

APPENDIX--IRRIGATED AGRICULTURE

Land Drainage Problem (Page II-40)

References

U. S. Dept. of Commerce, Bureau of Census, U. S. Census, 1950, Vol. IV, U. S. Gov't. Printing Office.

U. S. Dept. of Commerce, Bureau of Census, Census of Agriculture, 1954, U. S. Gov't. Printing Office.

Agricultural Conservation Program, Statistical Summary for 1955, U. S. Dept. of Agriculture, Dec. 1956, U. S. Gov't. Printing Office.

Bottum, J. C. Economic Newsletter No. 9, Farm Equipment Institute, Chicago, Illinois.

U. S. D. A.--A. R. S., Farm Output Information Bulletin No. 162, Aug. 1956, U. S. Gov't. Printing Office.

President's Water Policy Commission, A Water Policy for the American People, Vol. I, U. S. Gov't Printing Office, 1950, p. 161.

Israelsen, O. W. Irrigation Science, The Foundation of Permanent Agriculture in Arid Regions, The Faculty Association, Utah State Agricultural College, 1943.

Soil and Water Research Report and Recommendations of the Committee of the National Reclamation Association. Sept. 1951. (Mimeo.)

Steinel, A. T. History of Agriculture in Colorado. 1926.

Soil-Water-Plant Studies (Page II-48)

References

Robertson, D. W., Kezer, A., Sjogren, J., and Koonce, D. Studies on the critical period for applying irrigation water to wheat. Colo. Agr. Exp. Sta. Tech. Bul. 11. 1934.

Robertson, D. W., and Kezer, A. Residual effects of different irrigation treatments on the crops grown the succeeding year. Jour. Amer. Soc. Agron., 18:923-943. 1927.

Robertson, D. W., and Gardner, R. Factors affecting chlorosis in irrigated wheat. Jour. Agr. Res., 55:511-520. 1937.

Soil Surveys:

1927--Fort Collins Area - (U.S.D.A.) Bureau of Chemistry and Soils Cooperative Colorado Agricultural Experiment Station.

1929--Greeley Area (U.S.D.A.) Bureau of Chemistry and Soils Cooperative Colorado Agricultural Experiment Station.

1930--Longmont Area (U.S.D.A.) Bureau of Chemistry and Soils Cooperative Colorado Agricultural Experiment Station.

1932--Brighton Area (U.S.D.A.) Bureau of Chemistry and Soils Cooperative Colorado Agricultural Experiment Station.

1944--Western and Southeastern Baca (U.S.D.A.) Soil Conservation Service.

1944--Land Types Eastern Colorado--Colorado Experiment Station. L. A. Brown, D. S. Romine, R. T. Burdick, and Alvin Kezer.

1947--Akron Area (U.S.D.A.) B.P.I.-Cooperative Colorado Agricultural Experiment Station.

1949--Kit Carson County (U.S.D.A.) Soil Conservation Service Cooperative Colorado Experiment Station.

1955--Grand Junction Area (U.S.D.A.) Soil Conservation Service Cooperative Colorado Agricultural Experiment Station.

Gardner, R. Some soil properties related to the sodium salt problem in irrigated soil. U.S.D.A. Tech. Bul. 902. 1945.

Amemiya, M., Robinson, C. W., and Cowley, E. W. Reclamation of a saline alkali soil in the Upper Colorado Basin, S.S.S.A.P., 20:423-426. 1956.

Gardner, R., and Kelley, O. J. Relation of pH to phosphate solubility in Colorado soils. Soil Science, 50:91-102. 1940.

Gardner, R., and Robertson, D. W. The nitrogen requirement of sugar beets. Colo. Agr. Exp. Sta. Tech. Bul. 28. 1942.

Robertson, D. W., and Gardner, R. Restoring fertility to land where leveling operations have removed all the topsoil and left raw subsoil exposed. Proc., A.S.S. Beet Tech. Fourth General Session, pp. 33-35. 1946.

Whitney, Robert S., Gardner, Robert, Robertson, D. W. The effectiveness of manure and commercial fertilizers in retaining the productivity of subsoils exposed by leveling. Agron. Jour. 42:239-245. 1950.

Whitney, R. S., Robertson, D. W., and Gardner, R. Sugar beet fertilizer experiments on recently leveled land. Proc. Amer. Soc. Sugar Beet Tech., Fifth General Session, pp. 353-357. 1948.

Kunkel, R., Gardner, R., and Binkley, A. M. Fertilization of Red McClure Potatoes in the San Luis Valley in Colorado. Colo. Agr. Exp. Sta. Tech. Bul. 43. 1951

Mellor, G. L., Johnson, H. P. H., Gardner, R. Fertilizer placement for sugar beet production. The 1950 Proc., A.S.S.B. Tech., pp. 428-435. 1950.

Olsen, S. R., Cole, C. V., Watanabe. F.S., and Dean. L. A. Estimation of available phosphoros in soils by extraction with sodium bicarbonate. U.S.D.A. Circ. 939. 1954.

Schmehl, W. R., Olsen, S. R., Gardner, R., Romsdal, S. D., and Kunkel, R. Availability of phosphate fertilizer materials in calcareous soils in Colorado. Colo. Agr. Exp. Sta. Tech. Bul. 58. 1955.

Gardner, R., and Robertson, D. W. The beneficial effects from alfalfa in a crop rotation. Colo. Agr. Exp. Sta. Tech. Bul. 51. 1954

Miller, D. E., and Amemiya, M. Better quality mountain meadow hay. Colo. Agr. Exp. Sta. Tech. Bul. 54. 1954.

Rouse, H. K., Willhite, F. M., and Miller, D. E. High altitude meadows in Colorado. I. Effect of irrigation on hay yield and quality. Agron. Jour., 47:36-40. 1955.

Miller, D. E., Willhite, F. M., and Rouse, H. K. High altitude meadows in Colorado. II. The effect of harvest date on yield and quality of hay. Agron. Jour. 47:69-72. 1955.

Willhite, F. M., Rouse, H. K., and Miller, D. E. High Altitude meadows in Colorado. III. The effect of nitrogen fertilization on crude protein production. Agron. Jour. 47:117-121. 1955.

Franklin, W. T., Whitney, Robert S., Code. W. E., Reeve, R. C. Reclamation of saline-alkali lands in the Mosca-Hooper area, San Luis Valley. Colo. Agr. Exp. Sta. Gen. Ser. Paper 648. 1956.

APPENDIX--DRYLAND AGRICULTURE

References

Marion Clawson, The Western Range Livestock Industry, McGraw-Hill Book Company, 1950.

Colorado Agricultural Statistics 1948-1954, Colorado Department of Agriculture in Cooperation with the United States Department of Agriculture.

State Legislation for Better Land Use, A Special Report by an Interbureau Committee of the United States Department of Agriculture, U. S. Government Printing Office, 1941.

Stanley W. Voelker, Land-Use Ordinances of Soil Conservation Districts in Colorado, Technical Bulletin 45, Colorado Agricultural Experiment Station, March, 1952.

Proceedings of the Great Plains Agricultural Council, Laramie, Wyoming, July 24-27, 1955.

APPENDIX--PLAINS RANGE-LIVESTOCK OPERATIONS

References

Climatic Limitations (Page IV-3)

Beall, James M. 1956. Agricultural meteorology program of the U.S. Weather Bureau. Ms. 10 pp. typewritten. Paper presented at meeting of Section O. American Association for the Advancement of Science, New York City. Dec. 28, 1956.

Clawson, M. 1944. Range and livestock condition in relation to annual precipitation. Amer. Cattle Producer 25(8):12-19.

_____. 1947. Sequence in variation of annual precipitation in the western United States. Journal of Land and Public Utility Economics 23(3):271-287.

_____. 1948. Range forage conditions in relation to annual precipitation. Land Economics 24(3):264-280.

Nelson, E. W. 1934. The influence of precipitation and grazing upon black grama grass range. U.S.D.A. Tech. Bul 405.

Smoliak, S. 1946. Influence of climatic conditions on forage production of shortgrass rangeland. Jour. Range Mgmt.9(2):89-91.

Stoddart, L.A. and A.D. Smith. 1943. Range Management. McGraw-Hill Book Co. p.56.

Thomas, Gerald W. and V.A. Young. 1954. Relations of soils, rainfall and grazing management to vegetation. Texas Agricultural Experiment Station. Bul 786.

U.S. Forest Service. 1936. The western range. Senate Document 199., p. 140.

U.S. Weather Bureau. Climatological data--Colorado. Annual summaries, 1947-1956, and monthly reports.

Grazing Management (Page IV-8)

Costello, D.F. 1944. Efficient cattle production on Colorado ranges. Colo. Agr. Exp. Sta. Bul. 383-A.

Dyksterhuis, E.J. 1949. Condition and management of range land based on quantitative ecology. J. Rng. Mgmt. 2(3):104-115.

Johnson, W.M. 1953. Effect of grazing intensity upon vegetation and cattle gains on ponderosa pine-bunchgrass ranges of the front range of Colorado. USDA Circ. 929.

Johnson, W.M. 1956 The effect of grazing intensity on plant composition, vigor, and growth of pine-bunchgrass ranges in central Colorado. Ecology 37(4):790-798.

Land, R.L., O.K. Barnes, and F. Rauzi. 1956. Shortgrass range:--grazing effects on vegetation and on sheep gains. Wyo. Agr. Exp. Sta. Bul. 343.

McCorkle, J.S. and A. Heerwagen. 1941. Effects of range condition on livestock production. J. Rng. Mgmt. 4(4):242-248

Revegetation (Page IV-11)

Barmington, R.D. 1957. Problems involved in the reseeding of grasses on abandoned cropland. Colo. Agr. Exp. Sta. Gen. Ser. Pap. 658.

Barnes. O.K., R.L. Land, and A.A. Beetle. 1952. Grass establishment on Wyoming dryland. Wyo. Agr. Exp. Sta. Bul. 314.

Burnham, D.R. 1955. Reseeding abandoned cropland or depleted range areas. New Mex. Agr. Exp. Sta. Bul. 395

Costello, D.F. 1944. Natural revegetation of abandoned plowed land in the mixed prairie association of northeastern Colorado. Ecology.

Hervey, D.F. 1955. Annual Report, Forestry and Range Mgm't. Sec., Colo. Agr. Exp. Sta. Typewritten.

Hull, A.C., D. F. Hervey, C.W. Doran, and W. G. McGinnies. 1957. Seeding Colorado rangelands. Manuscript.

Rauzi, F., O.K. Barnes, and R.L. Land. 1954. Improving production of old seeded pastures. Wyo. Agr. Exp. Sta. Mimeo. Circ. 48.

Sitler, H.G. 1955. Returning cropland to grass in east-central Colorado. Unnumbered Draft Report. ARS.

Springfield, H.W. 1956. Relation of time of planting to establishment of wheatgrasses in northern New Mexico. Rcky. Mt. For. and Rng. Exp. Sta. Res. Note 24.

Stoddart, L.A. and A.D. Smith. 1955. Range Management. McGraw-Hill Book Co. New York.

Tucker, R.H. and D.F. Hervey, 1957. Planting non-irrigated cropland to grass. Colo. Agr. Ext. Ser. Circ. 187-A.

Soil and Water Conservation (Page IV-16)

Branson, F.A. 1956. Range forage production changes on a water spreader in southeastern Montana. J. Rng. Mgmt. 9(4):187-191.

Hubbard, W. A. and S. Smoliak. 1953. Effect of contour dykes and furrows on short-grass prairie. J. Rng. Mgmt. 6(1):55-62.

Johnson, V. W. and R. Barlow. 1954. Land problems and policies. McGraw Hill Book Co., Inc. New York.

Mooney, F. A. and J. A. Martin. 1956. Water spreading pays--a case history from South Dakota. J. Rng. Mgmt. 9(6):276-278.

Osborn, B. 1956. Cover requirements for the protection of range sites and biota. J. Rng. Mgmt. 9(2): 75-80.

Pierson, R. K. 1955. Range waterspreading as a range improvement practice. J. Rng. Mgmt. 8(4):155-158.

Rauzi, F. and R. L. Land. 1956. Improving shortgrass range by pitting. Wyo. Agr. Exp. Sta. Bul. 344.

Thomas, G. W. and V. A. Young. 1956. Range pitting and reseeding trials on the Texas range station near Barnhart, 1950-55. Tex. Agr. Exp. Sta. Prog. Rpt. 1882.

U.S.D.A. 1956. Agricultural conservation program - Colorado handbook for 1957. Unnumbered bulletin.

The Problem of Poisonous and Noxious Weeds (Page IV-24)

Hervey, D. F. 1949. Weed Killer 2,4-D gives varying results in tests on sagebrush. Colorado A & M News 3(9):3.

McIlvain, E. H. and D. A. Savage. 1949. Spraying 2,4-D by Airplane on Sand Sagebrush and other Plants of the Southern Great Plains. J. Rng. Mgmt. 2(2):43-52.

McIlvain, E. H. and D. A. Savage. 1952. Brush and weed control investigations on rangelands of the Southern Great Plains. Progress Report. U. S. So. Great Plains Field Sta.

The Problem of Rodents and Insects (Page IV-26)

Hansen, Richard M. 1956. New dispenser aid gopher control. Colo. Agr. Exp. Sta. Pamphlet 1-S.

List, George M. 1954. Western harvester ant control tests. Colo. Agr. Exp. Sta. Tech. Bul. 55.

Mickle, Gordon. 1957. Pocket gopher control in Colorado. Colo. State Univ. Ext. Serv. Circ. 186-A.