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HYDROLOGIC ASPECTS OF THE PINYON AND JUNIPER ERADICATION PROJECT ON THE FORT APACHE RESERVATION, ARIZONA*

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INTRODUCTION

For several years the Bureau of Indian Affairs and the Apache White River Tribe have been engaged in a program of vegetation modification, which many believe to be justified by the on-site benefit of increased forage. The vegetation modification program consists of substituting short-rooted grasses for deep-rooted trees, chiefly pinyon and juniper, and brush. The Bureau of Indian Affairs and the Geological Survey are cooperating in an investigation to obtain information on the effect of pinyon and juniper eradication on water yield and other hydrologic factors. The hydrologic investigation is adapted to the type of treatment activities currently underway in and near the Carrizo and Corduroy Creek basins.

Past studies in land treatment have shown that rigid controls are required for a precise evaluation of a change in the water yield. It has been observed that climatic and environmental fluctuations from year to year may have a greater effect on the runoff from a small drainage area than does land treatment. Therefore, in this study, consideration must also be given to changes not directly related to alterations in the vegetation. Two sets of paired watersheds were selected so that one watershed of each set can be used to measure changes in runoff that are not related to the land treatment.

The first 5 years of the study will be devoted to a pre-calibration period for collecting data on the differences in the hydrologic characteristics of the paired watersheds. After the pre-calibration period, one watershed of each pair will be cleared and, if necessary, seeded to assist in converting it to grassland. The other watershed will remain unaltered so as to give a measure of the effect of climatic fluctuations alone. A transition period of at least 2 or 3 years is expected to be required to stabilize the vegetation on the newly cleared ground. Water yield is the principal hydrologic factor that will be evaluated at the end of the transition period.

A water-budget study including measurements of precipitation, precipitation interception by vegetation, soil moisture, and surface runoff is to be used in the analysis. Although the mean annual precipitation on the project areas is more than 18 inches, the mean annual surface runoff is less than 1 inch. As runoff accounts for only 5 percent of the water loss in a water budget, a small change in the other hydrologic factors may produce a large increase or decrease in water yield.

Separate storms producing equal quantities of rainfall may produce large differences in runoff on the same watershed. The runoff from a storm of given size depends on the intensity rates of the precipitation and on the rate of infiltration, which in turn depends on soil moisture and the other antecedent hydrologic factors. A small increase in intensity may double the water yield. Furthermore, there are differences in intensity rates and total precipitation of the same storm, even in relatively short distances. These differences are related to the storm pattern, the altitude of the basin, and the orographic effect. Thus, to study the runoff characteristics of the pairs of basins, it is necessary to develop a relation between the storm runoff and precipitation for each watershed, and then to compare changes in the relations.

The 2 sets of paired drainage areas selected for this study of the effect of vegetation modification are the Cibecue Ridge watersheds and the Apache Ponds watersheds (Fig. 1). These watersheds are representative of the types of land surface from which it is feasible to eradicate vegetation by mechanical methods such as chaining and bulldozers. The use of mechanical methods limits the treatment to areas with slopes of 20 percent or less.

In addition, previously established gaging stations on Carrizo and Corduroy Creeks (Fig. 1) will be used to detect changes in base flow that may result from vegetation modification on more extensive areas in the Corduroy Creek watershed.

CIBECUE RIDGE STUDY AREA

Location

The Cibecue Ridge watersheds are in the Carrizo Creek drainage area, 2 miles southwest of the junction of Corduroy and Carrizo Creeks. The runoff from these watersheds drains toward Carrizo Creek and enters it downstream from the mouth of Corduroy Creek. Elevations of the basins range from 5,300 to 5,800 feet above mean sea level.

Physiography and Soils

The Cibecue Ridge study area is situated in an area of coalescing alluvial fans which have been dissected by tributaries of Carrizo Creek. Basalt flows of Pleistocene age partly filled the stream valleys of Carrizo and Corduroy Creeks, raising the base level of their tributaries and possibly causing the deposition of the alluvial fan materials. Subsequent downcutting of the lava-filled stream valleys also re-entrenched the tributary streams, and formed the present drainage system in the area.

Geology

Watersheds in the Cibecue Ridge study area are underlain by the Supai Formation of Pennsylvanain and Permian age, and by alluvial materials of Pleistocene and Recent age. The Supai Formation is composed principally of reddish-brown siltstone and silty fine-grained sandstone beds, which erode into ledges and slopes. The higher ridges immediately west of the study area are capped by the cliff-forming Fort Apache Limestone Member (Stoyanow, 1936) of the Supai Formation. Much of the fine-grained deposits and soils are derived from the Supai

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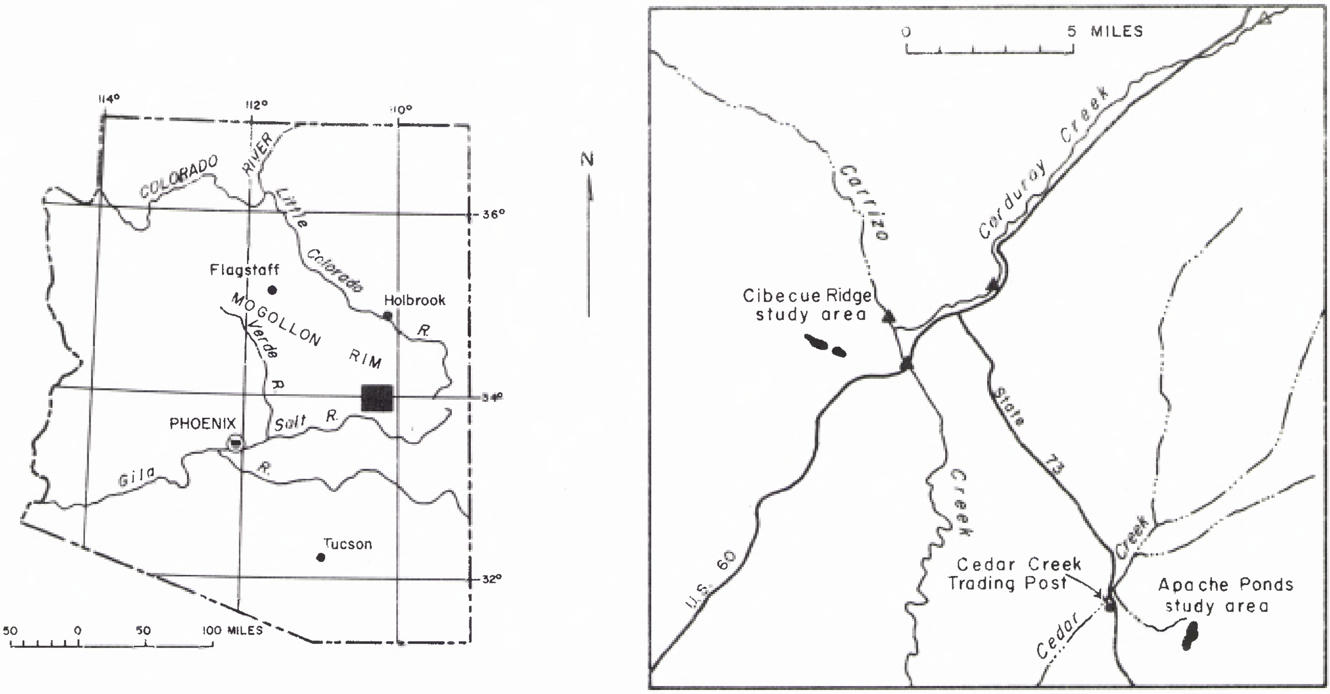

Figure 1.—Index maps showing the Cibecue Ridge and Apache Ponds study areas, Fort Apache Indian Reservation, Arizona. Triangles indicate the location of stream-gaging stations being operated before the start of the present study.

Formation, and represent several periods of alluviation. Deposits of gravel composed of quartzite, granite, and fine-grained igneous rocks in the Cibecue Ridge watersheds are similar to "Rim-gravel" deposits of Tertiary age on the Mogollon Rim. Other gravel deposits consist principally of limestone pebbles to boulders derived from nearby exposures of the Fort Apache Limestone Member.

Soils

The alluvial soils of the higher watershed, which is to be the treated area, range in depth from 4 feet at the upper end to 18 feet near the lower end. Remnants of an old soil profile with well-developed noncalcareous A and B horizons are present in parts of the basin. All or most of this profile has been eroded away in much of the basin. Limestone cobbles, derived from the cliff of the Fort Apache Limestone Member, are present in a calcareous C horizon in the central part of the basin.

The soils of the lower watershed, which is to be the control drainage area, have formed on bedrock or on alluvium derived from silty units of the Supai Formation. Grass-covered soil in the upper part of this watershed has a maximum depth of 4 feet. Surface stones cover more than 20 percent of the lower basin as compared with less than 2 percent of the higher basin.

Vegetation

Vegetation in both watersheds consists of a fairly dense stand of pinyon and juniper interspaced by open areas having a moderate grass cover. Quantitative measurements of grasses, forbs, and shrubs were made by the point analysis method on randomly located transects. Tree heights, stem diameters, ground cover, and numbers of each species were determined on each of 50 plots one twenty-fifth of an acre in size.

The 2 dominant tree species were Utah juniper and Pinyon pine. Arizona oak was present on 60 percent of the plots. Trees averaged 332 per acre in the watershed which is to be treated, and 553 per acre in the control watershed. Tree heights and stem diameters for both areas were similar. Eight herbaceous species, 16 shrub species, and 6 tree species have been identified. Native grasses, of which Blue grama and Sideoats grama were the most abundant, cover less than 2 percent of both watersheds.

After treatment, quantitative measurements of the grasses can be used to indicate the degree to which the grassland in the treated watershed is similar to the grassland in other cutover areas of the region. Although the studies of vegetation are made to evaluate the effect on hydrology of vegetation modification, the information obtained will also be valuable in showing the changes in forage.

Hydrologic Data

Runoff from the watersheds is measured at concrete controls installed at the lower end of each basin. These controls were designed to give water-yield records of above normal accuracy, and were constructed on nearly impermeable units of the Supai Formation to eliminate as much as possible the movement of subsurface water past the gaging station during periods of runoff.

Precipitation is measured by a weighing-type recording precipitation gage operated at the center of each watershed. In addition, several non-recording precipitation gages are along the periphery of each basin to help define storm patterns.

Measurements of water losses caused by trees intercepting precipitation are collected at 5 sites. The sites were selected to give representative samples covering the range in size and density of the predominant tree species, pinyon and juniper. Stem flow (the flow down the trunk of the tree) is also measured at the interception sites.

A neutron-scattering soil-moisture meter is used to measure changes in soil moisture at depths more than 6 inches. Gravimetric samples are collected to measure the moisture changes in the upper 6 inches of the soil mantle. Soil-moisture measuring sites are distributed throughout the basins to determine how differences in moisture changes are related to differences in topography, soil types, aerial cover of shrubs and trees, and in depth of soil mantle. During years of normal precipitation, changes in soil-moisture generally are limited to the upper 4 feet of the soil mantle.

Near the center of the watershed which is to be cleared, anemometers are set at distances of 1 and 8 meters above ground to determine the effect of vegetation on wind speed near the ground surface. In addition, the temperature and humidity are measured by a hygrothermograph. The instruments at this site provide data on microclimatic changes that may effect the evapotranspiration rate.

APACHE PONDS STUDY AREA

The second set of paired drainage areas used in this study is the Apache Ponds watersheds. They are in the Cedar Creek drainage area, 3 miles southeast of the Cedar Creek Trading Post. One watershed of 190 acres was cleared prior to the pre-calibration period and is used as the control area. The other watershed of 299 acres will be cleared at a later date. The basic problems and measurements are similar to those on Cibecue Ridge.

Runoff from the Apache Ponds watersheds is measured volumetrically in reservoirs at the lower end of each basin. Area-capacity curves, based on an accurate survey of each reservoir, are corrected annually to compensate for sediment deposition. Continuous recorders are installed to measure increments of change in water-surface elevation. Hydrographs of inflow to the ponds are computed from these records.

Evaporation and seepage studies are conducted during the summer months. Records on precipitation, humidity, wind velocity, and temperature are collected throughout the year. Soil moisture, soil temperature, and moisture tension records are collected during the summer at 1 site. Measurements of vegetational changes on the cleared watershed are made every other year.

SUMMARY

The basic objectives of the study of the pinyon and juniper eradication project are to evaluate the change in water yield produced by the proposed vegetation modification, and to develop a more comprehensive understanding of the functions of vegetation within the hydrologic regime in semiarid conditions. An attempt will be made to evaluate the major parts of the hydrologic cycle and define their interrelationships.

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