

Central Arizona Highlands

Peter F. Ffolliott

Introduction

The Central Arizona Highlands are a distinct biogeographic, climatic, and physiographic province that forms a diverse ecotone between the larger Colorado Plateau to the north and the Sonoran Desert ecoregions to the south (figure 1). The Highlands coincide approximately with the Arizona Transition Zone identified by ecologists, geologists and others. This region is one of the last in the Southwestern United States that was settled by European immigrants.

With its unique and diverse landscape, the Central Arizona Highlands has been the focus of a wide range of research efforts designed to learn more about the effects of natural and human induced disturbances on the functioning, processes, and components of the region's ecosystems. Spearheaded by the USDA Forest Service and its

cooperators, this research continues to lead to a comprehensive understanding of the ecology of the region, and to formulation of management guidelines that meet the increasing needs of people in the region and throughout the Southwestern United States.

Climate

The Central Arizona Highlands, similar to other areas in the state, are characterized by a cyclic climatic regime of winter precipitation, spring drought, summer precipitation, and fall drought. Precipitation usually comes from the northwest in the winter and from the southeast in the summer. Winter precipitation, often snow at higher elevations, is associated with frontal storms moving into the region from the Pacific Northwest. Surface thermal heating in the winter is less pronounced than in the summer; upslope air movement is relatively slow; cloudiness is common; and precipitation is usually widespread and relatively low in intensity.

The major source of moisture for summer rains is the Gulf of Mexico. This moisture moves into the Highlands from the southeast, passes over highly heated and mountainous terrain, rises rapidly, cools, and condenses. Summer storms, primarily convective, are often intense and local rather than widespread. Summer rains typically begin in early July, breaking the prolonged spring drought and providing relief to the hot weather of June and July.

Winter precipitation is more variable than summer in amount and time of occurrence from year-to-year. However, yearly variations in precipitation generally decrease with increases in elevation. Spring drought is often more detrimental to most plants and animals in the region than fall drought, due to the higher temperatures and wind conditions during the beginning of the growing season.

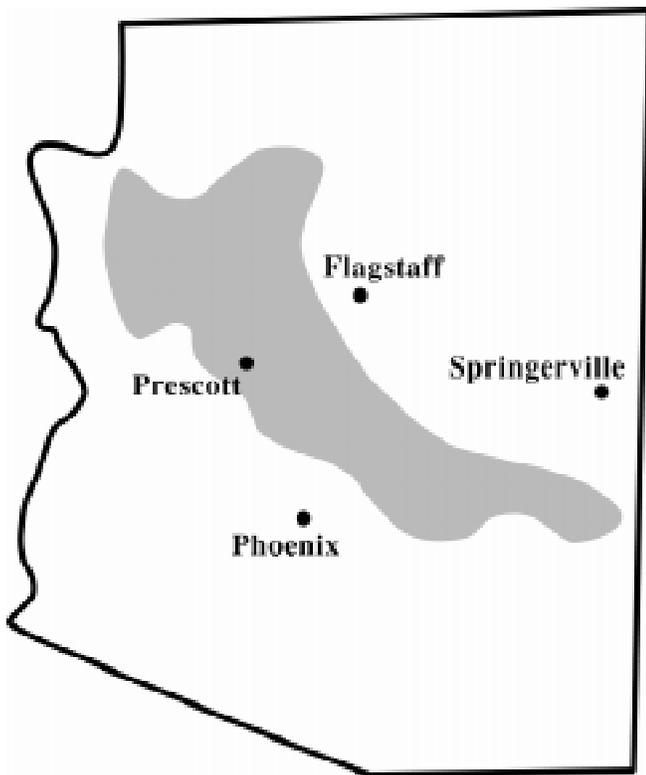


Figure 1. The Central Arizona Highlands.

Vegetation Types

Vegetation types in the Central Arizona Highlands include mixed conifer forests, ponderosa pine forests,

mountain grasslands, pinyon-juniper woodlands, and chaparral shrublands. The elevational and precipitation regimes for these vegetation types are in figure 2. These ecosystems contain: water, timber, forage, recreation opportunities, and habitats for a variety of big and small game animals, rodents, and game and non-game birds. A diversity of riparian ecosystems occur in, or adjacent to, stream systems and their floodplains throughout the region.

Mixed Conifer Forests

Seven coniferous and one deciduous tree species in a variety of mixtures characterize these high elevation forests. These species include Engelmann spruce (*Picea engelmannii*), blue spruce (*P. pungens*), Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), white fir (*Abies concolor*), corkbark fir (*A. lasiocarpa* var. *arizonica*), ponderosa pine (*Pinus ponderosa*), southwestern white pine (*P. strobiformis*), and quaking aspen (*Populus tremuloides*). Relatively little herbaceous vegetation is produced under dense overstories in these forests. As a consequence, carrying capacities for livestock and wildlife, which graze these forests in summer, are low in relation to other vegetative types in the region. Mixed conifer forests contain: water, timber, forage, recreation opportunities (camping, hunting, picnicking, hiking, and site-seeing), and habitats for a variety of big and small game animals, rodents, and game and non-game birds.

Annual precipitation in high elevation mixed conifer forests (above 9,500 ft) ranges from 30 to 45 inches and is usually in excess of potential evapotranspiration (figure 2). As a result, streams originating in this area are often perennial. Streams originating in low elevation mixed

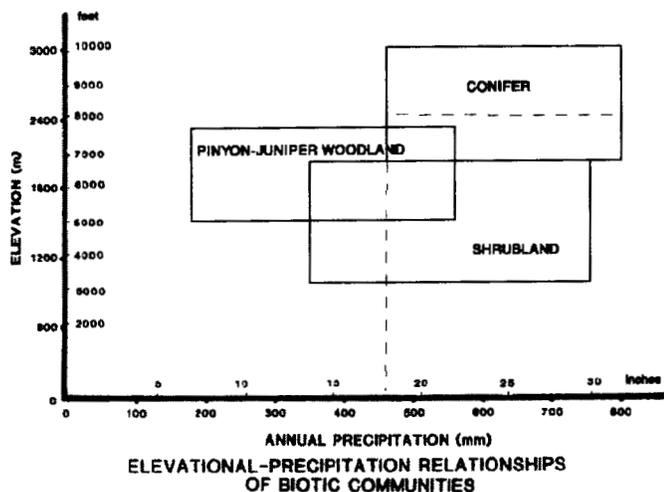


Figure 2. Precipitation-elevation relationships for vegetation types in the Central Arizona Highlands.

conifer forests (8,000 to 9,500 ft) are mostly intermittent. Snowmelt runoff is a significant source of annual runoff.

Soils, which vary in origin, are medium to moderately fine textured. Soil materials (regolith) are usually deep, allowing deep water penetration and storage. Mixed conifer forests are found over a range of slope and aspect combinations, although slope steepness is generally greater than in other vegetative types.

Ponderosa Pine Forests

Most of the ponderosa pine forests are at elevations between 5,500 and 8,500 ft on the Mogollon Plateau (figure 2). Although ponderosa pine trees dominate these forests, they often contain Douglas-fir, quaking aspen, and southwestern white pine at high elevations, and alligator juniper (*Juniper deppeana*) and Colorado pinyon (*Pinus edulis*) and its singleleaf form (*P. edulis* var. *fallax*) at low elevations. Gambel oak (*Quercus gambelii*) is scattered throughout. Grasses and grasslike plants, forbs, and half-shrubs grow beneath ponderosa pine overstories. Ponderosa pine forests are a valuable source of water, timber, forage, and recreation. Carrying capacities for livestock and wildlife, which graze these rangelands from late spring to early autumn, are relatively high. A diversity of wildlife species use these forests for cover and food, both seasonally and yearlong.

High transpiration rates and soil moisture deficiencies can curtail the growth of plants in ponderosa pine forests, which receive 20 to 30 inches of annual precipitation (figure 2). High elevation forests tend to have greater frequencies and amounts of precipitation than low elevation forests; although this can be altered by storm patterns and topography. Usually only a small amount of summer rain is converted into streamflow. Winter precipitation is the major source of runoff.

Basalt and cinders are the most common parent materials (57%), although sedimentary soils (43%) are also found throughout these forests. Topography is characterized by extensive flat, rolling mesas, intermixed with steeper, mountainous terrain, and a diversity of slope and aspect combinations.

Mountain Grasslands

Mountain grasslands, small in aggregate area, are scattered throughout the mixed conifer and ponderosa pine forests. While tree species are not usually part of these communities, isolated trees or shrubs occur through invasion from the adjacent forests on cinder cones and elevated places within the grasslands. The forest edge, where the 2 habitats come together, is a well delineated ecotone. Characteristic grasses are timothy (*Phleum pratense*), Arizona

fescue (*Festuca arizonica*), mountain muhly (*Muhlenbergia montana*), pine dropseed (*Blepharoneuron triholepis*), black dropseed (*Sporobolus interreptus*), mountain brome (*Bromus marginatus*), and the introduced Kentucky bluegrass (*Poa pratensis*). Many of these species have high forage value for livestock and wildlife species. Recreation is a valuable resource of these high elevation grasslands because they are intermixed with mixed conifer and ponderosa pine forests.

Annual precipitation ranges from 30 to 45 inches, with almost 50% occurring during the summer season. The general weather patterns of mountain grasslands coincide with those in the adjacent coniferous forests.

Soils are usually fine-textured alluviums that are frequently and easily compacted and often have poor drainage. Mountain grasslands occupy relatively level terrain compared to most of the adjacent forests.

Pinyon-Juniper Woodlands

These coniferous woodlands are below the ponderosa pine forests, at elevations between 4,500 to 7,500 ft (figure 2). Colorado pinyon is found throughout, with singleleaf pinyon (*Pinus monophylla*) occurring on limited areas. North of the Mogollon Rim, Utah juniper (*Juniperus osteosperma*), Rocky Mountain juniper (*J. scopulorum*), and one-seed juniper (*J. monosperma*) are intermixed with pinyon, while alligator juniper and Utah juniper are south of the Mogollon Rim. Annual and perennial grasses and grass-like plants, forbs, half-shrubs, and shrubs abound beneath the woodland overstories. Recreation, a resource of these woodland areas, is limited by summer temperatures and the relative lack of water. These woodlands are also an important source of firewood. Livestock, which spend their summers at higher elevations, graze in the woodlands in winter. These woodlands are also seasonal and yearlong habitats for many wildlife species.

There are wide fluctuations in weather patterns throughout the pinyon-juniper woodlands. Annual precipitation varies from 12 to 24 inches. Winter precipitation is usually rain with occasional snow. Evapotranspiration rates are relatively high in the growing season. Only during the coldest months of December through February is precipitation greater than the evapotranspiration rates.

Soils are derived from basalt, limestone, and sandstone parent material. Pinyon-juniper woodlands generally occupy extensive areas of gently rolling topography. With the exception of steep canyon walls, few slopes exceed 20% to 25%. All aspects are well represented.

Chaparral Shrublands

Chaparral shrublands occur on rough, discontinuous, mountainous, terrain south of the Mogollon Rim. Chaparral

stands consist of a heterogenous species mix in many locations, but often only 1 or 2 species dominate. Shrub live oak (*Quercus turbinella*) is the most prevalent species, while true (*Cercocarpus montanus*) and birchleaf mountainmahogany (*C. betuloides*), Pringle (*Arctostaphylos pringlei*) and pointleaf (*A. pungens*) manzanita, yellowleaf (*Garrya flavescens*), hollyleaf buckthorn (*Rhamnus crocea*), desert ceanothus (*Ceanothus greggii*), and other shrub species are included in the chaparral mixture of shrub species. Annual and perennial grasses, forbs, and half-shrubs are present, particularly where the overstory canopy is open or only moderately dense. Although the recreational value (hiking, camping, and hunting) of chaparral is lower than that of higher elevation vegetation types, its close proximity to major population centers provide it with an advantage. Research has also determine that chaparral areas are major sources of water if vegetation control is exercised. Chaparral rangelands are often grazed year-long by livestock, because evergreen plants common to the shrublands provide a continuous forage supply. A variety of wildlife species are found in chaparral shrublands, with comparatively high populations often concentrated in fringe areas.

Average annual precipitation varies from about 15 inches at the lower limits of the chaparral shrublands (3,000 ft) to over 25 inches at the higher elevations (6,000 ft) (figure 2). Approximately 60% of the annual precipitation occurs as rain or snow between November and April. The summer rains fall in July and August, which are the wettest months of the year. Annual potential evapotranspiration rates can approach 35 inches (Hibbert 1979).

Chaparral soils are typically coarse-textured, deep, and poorly developed. Granites occur on more than half of the shrublands. The topography is characterized by mountain ranges dissected by steep-walled gorges and canyons. Slopes of 60% to 70% are common. All aspects are represented.

Riparian Ecosystems

Three riparian ecosystems, delineated by elevation, are recognized in the Central Arizona Highlands. Riparian vegetation that occurs along the flood plain of stream channels are typically composed of herbaceous species of *Carex*, *Eleocharis*, *Juncus*, and *Scirpus* and produce the characteristic dark green edge along the channel systems. Woody plants, including saltcedar (*Tamarix pentandra*), sycamore (*Platanus wrightii*), and cottonwood (*Populus fremontii*), that are often associated with riparian ecosystems are typically found higher up on the terraces next to the flood plains.

In ecosystems below 3,500 ft, many of the ephemeral streams have broad alluvial floodplains that can support herbaceous plants and terraced bottoms that often support high densities of deep-rooted trees including saltcedar,

sycamore, cottonwood, palo verdes (*Cercidium spp.*), and other species.

Riparian ecosystems between 3,500 and 7,000 ft contain the greatest number of plant species and the greatest canopy cover. Besides the characteristic herbaceous plants along the flood plain, cottonwood, willow (*Salix spp.*), sycamore, ash (*Fraxinus velutina*), and walnut (*Juglans major*) are typically found on the terraces, with 3 or 4 species often occurring together.

Above 7,000 ft, herbaceous species of *Carex*, *Eleocharis*, *Juncus*, and *Scirpus* predominate along the edge of the stream channels. Willow, chokecherry (*Prunus virens*), boxelder (*Acer negundo*), Rocky Mountain maple (*A. glabrum*), and various coniferous tree species occupy the higher terraces.

Because of the abundance of water, plants, and animals, riparian areas provide valuable recreation opportunities as well as forage for livestock and wildlife in an otherwise arid environment. Riparian ecosystems are prime habitats for many game and non-game species of wildlife and fish.

Collectively, climatic characteristics of riparian ecosystems exhibit a wide range of conditions due to large elevational differences and distributions of associated mountain ranges and highlands. The key characteristic of the riparian system is the availability of water throughout the year or at least during the growing season.

Soils at the higher elevations generally consist of consolidated or unconsolidated alluvial sediments from parent materials of the surrounding uplands. Soil depths vary in riparian ecosystems, depending upon the stream gradient, topographic setting, and parent materials. Soils on the flood plains at lower elevations consist of recent depositions, tend to be uniform within horizontal strata, and exhibit little development. The alluvial soils in all ecosystems are subject to frequent flooding and, as a consequence, are characterized by a range of textures. Riparian ecosystems vary from narrow, deep, steep-walled canyon bottoms, to intermediately exposed sites with at least one terrace or bench, to exposed, wide valleys with meandering streams.

Initial Research Emphasis

One situation that conditioned and circumscribed people's behavior throughout Arizona and the Southwestern United States was the perennial shortage of water. The expected but variable supplies of surface water have long since been appropriated. Electricity and electric pumps enabled access to previously unavailable groundwater sources, while the favorable climate resulted in an increase in agriculture and urbanization. As a consequence, nearly all of the increased water supplied to this rapidly

growing area was pumped from underground basins. This has caused a steady decline in regional water tables, which, in turn, has affected local economies. Many acres that formerly supported agriculture have been abandoned, converted to housing developments, or switched to an alternate source of water, such as the Central Arizona Project (CAP) water that became available in the late 1980s. However, the water situation, especially in the heavily populated areas, has had little effect on people's behavior, except for the farmer (Wilson 1997). Within any user group (household, municipal, commercial, industrial, or agriculture), the willingness to pay for water varies significantly depending on the benefits obtained from its use. For example, as the price of water increases, the quantity demanded by various users changes because of differences in their ability to purchase water. Household users have the highest willingness to pay and one of the lowest quantities demanded (about 2 to 3 acre-ft/acre/yr assuming 4 families per acre). On the other hand, the willingness of farmers to pay is far less than any other user. However, their crops require much more water (5 and 6 acre-ft/acre/yr to grow cotton and alfalfa, respectively). To put this in perspective, the native desert around Phoenix uses about 0.5 acre-ft/acre/yr. When the cost of water sufficiently reduces the farmer's profit, he is forced to stop farming and either abandons or sells his land to a developer who provides what many homeowners desire: artificial lakes, golf courses, pools, and green lawns. Conversion of water previously used for agriculture (5 or 6 times that used by a household), therefore, has the potential to sustain growth of municipalities and industry for some years into the future.

Barring conversion of saline water, additional importation of outside water, advancements in rainmaking, and rigorous conservation measures, regional residents must rely on the variable surface and diminishing groundwater supplies. In response to this situation, the initial direction of research in the Central Arizona Highlands focused on investigating the potentials for increasing water yields from forests, woodlands, and shrublands of the region through vegetative manipulations (Barr 1956). Numerous watersheds were instrumented with various climatic and hydrologic measuring equipment by the USDA Forest Service and its cooperators in the late 1950s and throughout the 1960s to study the effects of vegetative clearings, thinnings, and conversions on water yields under controlled, experimental conditions.

These watersheds formed a research network, called the *Arizona Watershed Program*, of public agencies and private groups interested in obtaining more water for future economic growth while maintaining the state's watersheds in good condition. This collaborative program was the focus of watershed research in the Central Arizona Highlands through the 1960s, 1970s, and into the early 1980s.

Multiple Use Considerations

Vegetative manipulations that were tested on the instrumented watersheds not only influenced the water yield, but also affected all of the other natural resource products and uses of the forests, woodlands, and shrublands in the region. Therefore, the USDA Forest Service and its cooperators enlarged the research program to evaluate the effects of vegetative manipulations on the array of multiple uses contained in the ecosystems studied. Results from this research showed that vegetation can often be managed to increase water yields while providing timber, forage, wildlife, and amenity values in some optimal combination. This finding was not surprising, as many of the vegetation management practices studied for their water-yield improvement possibilities are common in principle and application to management programs

that are often implemented to benefit other natural resources.

Much of the research in the Central Arizona Highlands has centered on the Sierra Ancha Experimental Forest above Roosevelt Lake; the Three-Bar Wildlife Area west of Roosevelt Lake; the Whitespar, Mingus Mountain, and Battle Flat watersheds in the vicinity of Prescott; the Beaver Creek watersheds along the Mogollon Rim south of Flagstaff; and Castle Creek, Willow Creek, Thomas Creek, and Seven Springs watersheds in the White Mountains of eastern Arizona. Descriptions of research designs, characteristics of research sites, cooperators involved, results and implications, and the current status of research activities on these and associated sites are presented in the following chapters. The history of research efforts in the riparian ecosystems of the Central Arizona Highlands is also presented.

