Arizona's Diverse Vegetation and Contributions to Plant Ecology

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In the 1880's, Mr. and Mrs. J.C. Lemmon were among the few botanists to collect plants in Arizona during the conflict between Apaches and European settlers. Unlike many settlers, the Lemmon's traveled safely. Apparently the Apaches considered plant collecting a form of insanity (Benson 1959). Many have continued collecting plants and studying vegetation in the groundbreaking and unyielding tradition of the Lemmons. These subsequent contributions have been at the forefront of plant ecology, and their legacy spreads well beyond the state borders.

Arizona extends over 7 million acres between 31 and 36° north latitude, and about 80% of the area is state or federal public land. The climate is generally arid, with a bimodal precipitation pattern of wet summer months (July-September), moderately moist winter months (December-March) and a very hot and dry spring and early summer (Green and Sellers 1964). The proportion of winter precipitation increases to the north. Additionally, dramatic elevational gradients in Arizona alter the magnitude of the temperature and precipitation values. This elevational gradient ranges from 68 feet near the Colorado River in southwest to over 12,630 feet on Humphery Peak in the north. The Mogollon Rim is a 1,600-2,300 foot escarpment that rises above the central desert regions. Rising above the Rim to greater than 9,800 feet are the White Mountains to the east, and San Francisco Mountains to the north. In the southeast, a basin and range physiography dominates the landscape with valleys at 2,600-4,900 feet elevation separated by mountain ranges reaching 8,200-10,800 feet. These sharply rising mountain ranges are often referred to as sky islands surrounded by a sea of desert.

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As expected, the elevation gradient and associated climate gradient provide the ingredients for a rich and diverse flora. Over 3,400 vascular taxa are recognized (Kearney et al. 1960), and an ongoing flora revision will increase that number (Vascular Plants of Arizona Editorial Committee 1992). Plant taxa range from subtropical species with distributional and genetic affinities with taxa in Mexico and Central America, Mediterranean species with affinities in California, and temperate and alpine species with affinities to the north and east including the Rocky Mountains.

The biotic diversity and the dramatic elevation/climate gradients in Arizona have provided important cases for a rich discussion concerning the organization of plant communities. The life zone classification was developed by Marriam (1898) while working around Humphrey Peak north of Flagstaff. His approach described a series of discrete and sharply differentiated biotic communities. In contrast, Shreve (1915) and Whittaker and Niering (1965) applied a more gradual or continuum approach to describing the distribution of plant species along the elevation/climate gradients in the sky islands of southeastern Arizona. They suggested that the abundance of species along the gradients were dependent on the tolerance of individual species to the physical environment, and largely independent of other plant species.

Although the debate focuses on the factors controlling species distribution, the discrete approach has decided advantages when the goal of classification is to improve communication about the general appearance and location of vegetation. In this paper, we use a discrete classification to communicate the variety and dynamics of nine plant communities in Arizona: desert scrub, desert grassland, chaparral, northern desert scrub, juniper-pinyon woodland, oak woodland, ponderosa pine forest, mixed conifer forest and riparian forest. By using the discrete approach for communication, we are not endorsing its use for describing the factors that determine species distributions.

Desert Scrub

Covering about 25 million acres (Nichol 1937) in southern and western Arizona, the desert scrub is a sparse, low stature vegetation of shrubs, short trees, cacti and scattered perennial herbs (Fig. 1). Conspicuous species are saguaro (*Carnegiea gigantea* (Engelm.) Britt. & Rose), palo verde (*Cercidium* spp.) bursage (*Ambrosia* spp.) and creosote (*Larrea tridentata* (D.C.) Coville). Generally, annual precipitation does not exceed 10 inches, and precipitation in this area has the greatest annual variation in the United States (Hidy and Klieforth 1990).

The majority of biomass productivity occurs in the spring following winter rains, but some significant growth can occur following summer rains. Spring wildflower displays are most common when fall precipitation exceeding 1 inch stimulates germination, and sufficient winter and spring precipitation sustains growth until flowering in March (Beatley 1974). Germination and survival of many species are more common under other plants than in

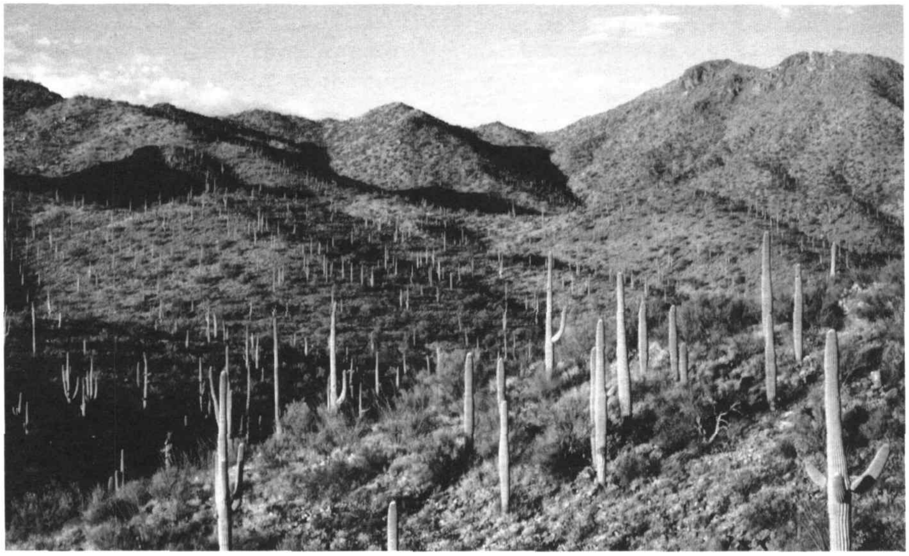

Fig. 1. *Hot Desert vegetation with saguaro, foothill palo verde (*Cercidium microphyllum *(Torrey) Rose & Johnson) and triangel leaf bursage (*Ambrosia deltoidea *(Torrey) Payne) in Tucson Mountains.*

open areas (McAuliffe 1988). This is commonly referred to as a nurse plant relationship. Bursage, living or dead, is a common nurse plant while creosote rarely serves as a nurse plant.

In 1903, the Carnegie Institute established the Desert Laboratory in Tucson as one of the first facilities dedicated to the study of desert ecosystems (Bowers 1990). The genus *Carnegiea* used for the saguaro cactus reflects the early involvement of the Carnegie Institute Desert Laboratory. The world's oldest, regularly measured plots that monitor individual plant size and mortality are located on this facility (Goldberg and Turner 1986). This long term information has shaped the understanding and approach to studying desert vegetation dynamics worldwide.

The development of packrat midden analysis in Arizona desert scrub facilitated the study of vegetation dynamics in arid environments over geologic time-frames. The middens include plant material and various attractive objects collected by packrats (*Neotoma* spp.) and preserved in a matrix of crystallized urine in their latrine caverns (Betancourt et al. 1990). Analysis of the plant material and radiocarbon dating were originally applied to describe changes in desert vegetation over the last 40,000 years, but it has since been applied to a variety of ecosystems worldwide.

According to packrat midden analyses, much of this area has changed from a juniper-oak woodland as the warmer and drier post-Pleistocene climate developed over the last 11,000 years (Van Devender 1990b). The recent increase in annual plants from the Mediterranean region, including red brome (*Bromus rubens* L.) and red filaree (*Erodium cicutarium* (L.) L'Her.) represent a vegetation change (Burgess et al. 1991) equal to the geologic time-frame changes because these recent arrivals with increased biomass depress native wildflowers and promote wildfires. An increased frequency of wildfires may then lead to further changes in desert scrub including the loss of some fire sensitive species such as some cacti.

Desert Grassland

Spread over nearly 15 million acres in southeastern Arizona, and scattered areas in central Arizona, the desert grassland includes herbaceous, shrubby and short tree species with at least 20-40% bareground. The ability of these diverse lifeforms to persist and co-exist has led some to suggest that mixed shrub savanna is a more accurate name. Conspicuous species are velvet mesquite (*Prosopis velutina* Woot., burroweed (*Isocoma tenuisecta* Greene), snakeweed (*Gutierrezia sarothrae* (Pursh.) Britt. & Rusby), Arizona cottontop (*Digitaria californica* (Benth.) Henr.), tobosa (*Hilaria mutica* (Buckl.) Benth.), and grama grasses (*Bouteloua* spp.). Generally, annual precipitation is between 10-16 inches/yr. The majority of herbaceous biomass production occurs in August and September, and total net annual productivity is usually less than 1,300 lb/acre (Schmutz et al. 1991). Woody species growth is most abundant in spring when winter moisture is utilized, and some growth occurs in summer with sufficient precipitation.

The study of historic vegetation changes have been facilitated by the development of repeat photography techniques and the establishment of the Santa Rita Experimental Range in southern Arizona (Fig. 2). The Changing Mile by Hastings and Turner (1965) was one of the earliest and most influential applications of repeat photography (comparing old and contemporary photographs from the same location) to describe vegetation dynamics. Some of the original photographs were taken on the Santa Rita, which was established as the world's first range experiment station in 1903. Research initially focused on sustainable livestock production, but the focus quickly expanded and has continued to include more general plant ecology pursuits (Martin 1975). The Bureau of Plant Industry initially administered the area. The Forest Service then administered the area from 1915 until 1989, when it was transferred to the State of Arizona and administration was assumed by the University of Arizona College of Agriculture.

In the past 100 years, the abundance of woody species particularly velvet mesquite has increased and grass has decreased. Hastings and Turner's (1965) classic repeat photography shows the magnitude of this change and that while woody species were present 100 years ago their abundance has clearly increased. Several hypotheses have been presented to interpret this vegetation change including shifts in seasonal

Fig. 2: *Desert Grassland vegetation dynamics depicted with repeat photography from Santa Rita Experimental Range. A livestock exclosure constructed in 1916 is visible on the right side of the images, and the similarity of vegetation dynamics within and outside the exclosure suggest that livestock grazing is not necessary to produce dramatic vegetation changes. Instead, weather patterns and the arrival of new species can be more dominant in producing these vegetation changes than livestock grazing.*

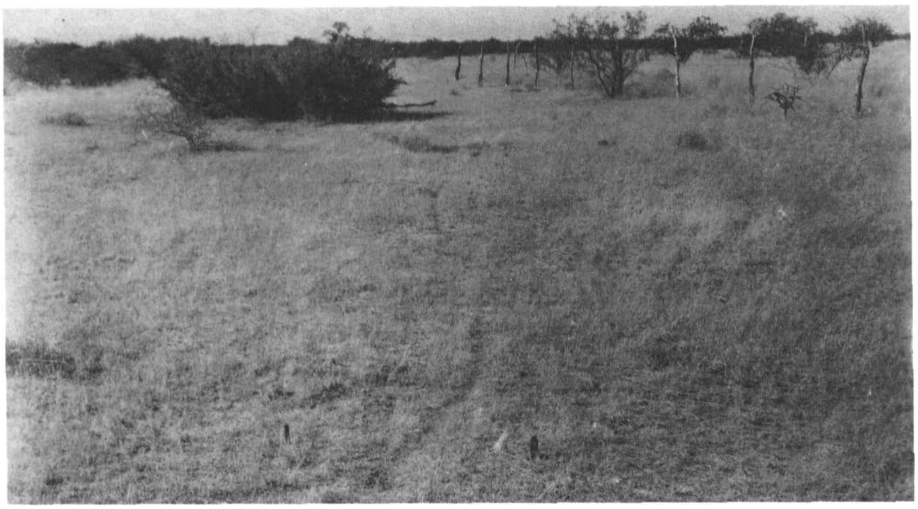

Fig. 2A: *In December 1922, annual grama grasses (*Bouteloua aristidoides *(H.B.K. Griseb. and* B. barbata *Lag.) appear to be the dominant herbaceous species with scattered velvet mesquite and desert hackberry (*Celtis pallida *Torr.) small trees and shrubs. The 3 metal stakes at the bottom of the picture are the plot markers for a permanent plot where charting of individual plants was performed.*

Fig. 2B: *In July 1970, the small shrub burroweed and chain fruit cholla cactus (*Opuntia fulgida *Engelm.) dominate the scene. Inside and outside the exclosure, the majority of the burroweed plants are dead, and they died within the previous 12 months. There are also a number of dead cacti.*

precipitation toward winter months (Neilson 1986), decreased fire frequency from reduced fuels and fire suppression (Bahre and Shelton 1993; Humphrey 1958), decreased grass cover from grazing (Glendenning and Paulson 1955) and wild hay harvesting (Bahre 1987), and seed dispersal by livestock (Glendenning and Paulson 1955).

According to packrat midden analyses, the dominant woody species have changed from pine, juniper and oak to the more subtropical velvet mesquite and desert hackberry (*Celtis pallida* Torr.) over the last 11,000 years as the warmer and drier post-Pleistocene climate developed (Van Devender 1990a,b). However, the dominant grass species are largely the same as during the Pleistocene. The recent increase and spread of the south African Lehmann lovegrass (*Eragrostis lehmanniana* Nees.) from isolated seedings (Anable et al. 1992) represents a vegetation change of a magnitude similar to the contemporary woody species increase and the disappearance of the pine, junipers and oaks over the last 11,000 years. Because lovegrass spread does not require disturbance associated with livestock grazing (McClaran and Anable 1992), it appears that the spread will continue regardless of management actions.

Chaparral

Chaparral vegetation occurs south of the Mogollon Rim on rough mountainous terrain between 3,000 and 9,800 feet (Fig. 3). The extent of the chaparral depends on definition and varies between 6 million acres (Nichol 1937) and 4 million acres (Cable 1975' Ffolliott and Thorud 1975). Dominant shrubby species are similar in appearance to the sclerophyllous species that dominate true chaparral vegetation (Plummer 1911). However, Arizona chaparral differs from "true" chaparral by having summer precipitation in addition to winter precipitation that occurs in both. Total annual precipitation is between 15-27 inches, with over 50% typically falling in the cooler months.

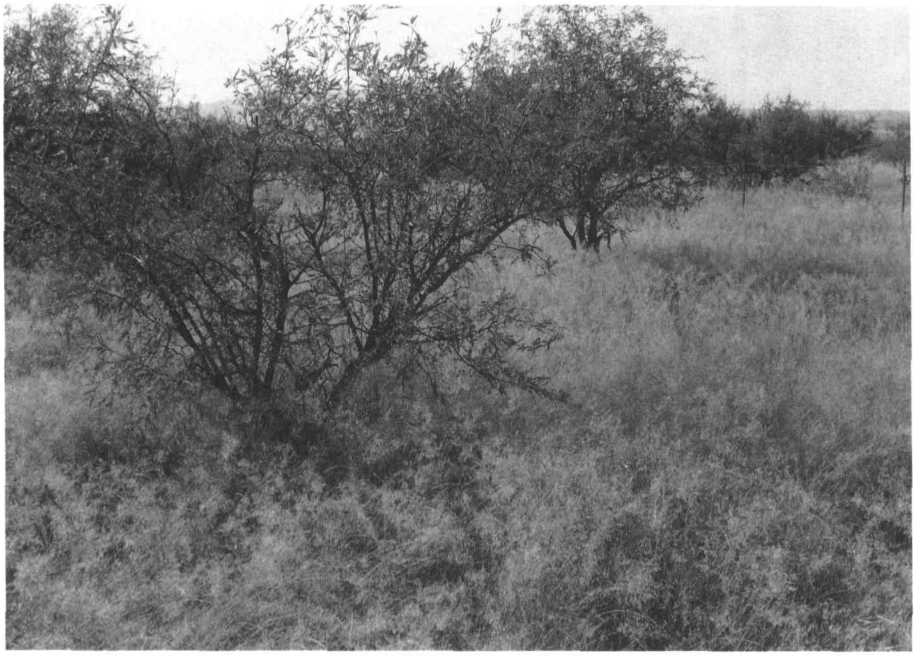

Fig. 2C: *In September 1993, the south African Lehmann lovegrass dominates the scene both inside and outside the exclosure. The grass was aerially seeded in the area in the mid-1970's. Burroweed is present beneath the grass canopy, but cactus plants are very scarce.*

Numerous shrub species occur in Arizona chaparral, but rarely do more than two species co-dominate a particular stand (Cable 1975). The most common species is shrub live oak (*Quercus turbinella* Greene). Other important species include Emory and Palmer oaks (*Q. emoryi* Torr. and *Q. dunnii* Kellog), species of mountain mahogany (*Cercocarpus* spp.) and several species of manzanita (*Arctostaphylos* spp.). Understory species are typically scarce, highly variable and the same species found in adjacent vegetation types (which includes ponderosa pine forest, juniper-pinyon woodland, oak woodland and desert grassland). Annual production of understory species is typically around 175 lb/acre.

Like true chaparral, Arizona chaparral is prone to fire. Many species, particularly the oak-mountain mahogany complex, are vigorous sprouters following fire and rapidly reestablish even after severe burns (Pase and Lindemuth 1971; Pond and Cable 1960). Other species, such as the manzanitas, do not sprout but germinate profusely following fire (Pase 1965).

Livestock were first introduced into the Arizona chaparral in 1874 when the first cattle were driven into Tonto Basin in central Arizona (Croxen 1922). Cable (1975) suggested that chaparral, at this time, had considerably lower shrub cover and included good stands of interspersed grasses. Peak stocking did not occur until 1900 when stocking levels were estimated as being 15 to 20 times the carrying capacity of the range (Croxen 1926). A major drought occurred in 1903-1904 and resulted in the death of many cattle and a permanent reduction in stocking. Cable (1975) hypothesized that this period of intense livestock grazing and the continuing suppression of fire resulted in an increased density of overstory species and reduction in herbaceous species.

Chaparral research in the 1950's began to emphasize the conversion of chaparral to grass-forb cover to increase water yield for downstream users (Barr 1956). Calibrated watersheds were established in four areas (Whitespar, Mingus, Threebar, and Natural Drainage watersheds) to evaluate the effects of conversion on water yield. Studies on these watersheds laid important groundwork that helped plant ecologists better understand dynamics of the hydrologic cycle in arid environments (Ffolliott and Thorud 1975). Conversion programs, however, were effectively suspended when the use of herbicides attracted international attention and resulted in reconsideration of both the methods and desirability of conversion (Ffolliott and Thouud 1975, Shoecraft 1971).

Northern Desert Shrub

Most of the 4 million acres (Nichol 1937) of northern desert shrub occurs in Arizona north of the Colorado River: an area known locally as the "strip" which also includes Grand Canyon National Park. Shrubby species dominate this vegetation type which occurs between 2,300-5,900 feet. Annual precipitation is approximately 4-14 inches with approximately 50% falling in June-September when the majority of herbaceous plant growth occurs (Arizona Inter-Agency Range Technical Subcommittee 1969; Judd 1962).

Much of the northern desert shrub is dominated by pure stands of big sagebrush (*Artemisia tridentata* Nutt.). Pure stands of blackbrush (*Coleogyne ramossissima* Torr.) also occurs in the northwestern portion of the state. Locally important shrubs are winterfat (*Eurotia lanata* (Pursh) Moq.) and fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.). There is a diverse group of herbaceous understory species, and common species are blue grama, (*Bouteloua gracilis* (H.B.K.) Lag.), needle-and-thread grass (*Stipa comata* Trin. & Rupr.), Indian ricegrass (*Oryzopsis hymenoides* (Roem. & Schult.) Ricker), squirreltail (*Sitanion hystrix* (Nutt.) J.G. Smith), and western wheatgrass (*Agropyron smithii* (Rydb.) (Judd 1962; Nichol 1952).

Understory production is highly variable from year to year and from stand to stand and is inversely related to cover of the shrub canopy. Most herbaceous production occurs in the summer and standing biomass can range from 350 to 1,000 lb/acre (Ffolliott and Throud 1975).

Fig. 3. Chaparral vegetation near Mayer, Arizona is dominated by shrub live oak and other small shrubs with very little herbaceous biomass.

Juniper-pinyon Woodland

Covering about 12 million acres in northern, northeastern and scattered areas in southeastern Arizona (Nichol 1937), the juniper-pinyon woodland varies from widely scattered trees and shrubs in grasslands to dense woodlands with little herbaceous understory. Conspicuous species are one seed and Utah junipers (*Juniperus monosperma* (Engelm.) Sarg. and *J. , osteosperma* (Torr.) Little), pinyon pine, (*Pinus edulis* Engelm.), algerita, (*Berberis fremontii* Torr.) western wheatgrass and blue grama. Annual precipitation ranges from 12-20 inches, and some winter precipitation occurs as snow (Springfield 1976).

Woody species growth is most abundant in spring and early summer, whereas herbaceous production is greater in the summer when warm season species are present (Springfield 1976). Herbaceous production ranges from 45-450lb/acre and is inversely related to tree cover.

In the past 100 years, the extent and density of the woodland has increased dramatically (Springfield 1976). Decreased fire frequency from suppression and reduced fuels from livestock grazing is the generally accepted interpretation of this increase. Management efforts to reduce tree cover and density were most common between 1950-1970, but only about 5% of the area ever experienced tree removal and less than 1% was ever retreated (Dalen and Snyder 1987). Current efforts to reintroduce fire are hindered by the reduction of herbaceous biomass following the increased tree cover.

Evidence from packrat midden analyses suggest that during the cooler and wetter Pleistocene period more than 18,000 years ago, this area supported mixed conifer vegetation, and the junipers and pinyons arrived about 8-10,000 years ago from areas to the south and southeast (Betancourt 1987). It is possible that some part of the recent spread of these trees is a continued expression of this geologic time-frame expansion.

Oak Woodland

Oak woodland covers about a million acres on the slopes of the sky islands in southeastern Arizona, and its appearance ranges from open savannas to dense woodlands (McClaran et al. 1992). Conspicuous species are Arizona white oak, Mexican blue oak, and Emory oak (*Quercus arizonica* Sarg., *Q. oblongifolia* Torr. and *Q. emoryi* Torr.), point leaf manzanita (*Arctostaphylos pungens* H.B.K.); and warm-season grasses including gramas (*Bouteloua* spp.) and bluestems (*Andropogon* spp.). Precipitation varies from 20-26 inches/yr and only rarely occurs as snow (McClaran et al. 1992).

Spring is the primary period of tree growth following sufficient winter moisture, but during dry winters some trees become deciduous and resume growth with the onset of summer rain. In contrast, herbaceous growth is largely in summer, but some cool season species under tree canopies grow in the spring including pinyon ricegrass (*Piptochaetium fibriatum* (H.B.K.) Hitch.) and prairie junegrass (*Koeleria pyramidata* Lam.) Beauv. Oak cover can reduce herbaceous biomass production from 140 lb/acre down to 80 (McPherson 1992).

Disparate descriptions of historic changes in lower boundary of oak woodland show an upslope retreat (Hastings and Turner 1965) and relatively static boundaries (Bahre 1991). From 1880-1940, extensive areas of oak were cut for domestic and smelting fuel, but much of the cut-over area again supports oak because the cut trees produced stump sprouts that have matured (Bahre and Hutchinson 1985).

Recently, McPherson et al. (1993) described the first application of new techniques in stable carbon isotope analysis to describe a downslope movement of oaks. This technique is based on the different concentration of carbon isotopes in woody species (C3) and warm season grasses (C4), and the concentration of the carbon isotopes in the soil will reflect the type of vegetation growing above the soil. Subsequent carbon[14] analysis suggests that the downslope movement has occurred over the last 700-1,000 years. This relatively recent, pre-historic downslope movement is contrary to the general pattern of unslope retreat of oak since the Pleistocene (Betancourt et al. 1990).

Ponderosa Pine Forest

Primarily above the Mogollon Rim in north and eastern Arizona and scattered areas on the sky islands in the southeast, the 4 million acre ponderosa pine forest (Nichol 1937) varies from dense, dog-hair thickets of pine, park-like stands of large trees with herbaceous understory. Conspicuous species are ponderosa pine (*Pinus ponderosa* Lawson), Gambel oak (*Quercus gambelii* Nutt.), blue grama mountain muhly (*Muhlenbergia montana* (Nutt.) Hitch.), squirreltail and Arizona fescue (*Festuca arizonica* Vasey). Annual precipitation ranges from 13-20 inches with a significant proportion occurring as snow (Clary 1975).

Tree growth and cool season herbaceous growth is primarily in the late spring and early summer, and warm season grass growth is generally later in July-August (Clary 1975). Herbaceous growth declines from 890 lb/acre down to less than 175 as tree density and cover increases.

Northern Arizona has been the site of continuous observation of an increase in tree density and decreased grass cover over the last 100 years (Arnold 1950; Cooper 1960; White 1985). This long-term research utilized study areas that were established near the turn of the century and produced some of the most precise descriptions of vegetation change available in the western United States. The results of this impressive research suggest that decreased fire frequency from suppression and reduced fuels from livestock grazing was responsible for this vegetation change. Ponderosa pine germination requires bare mineral soil and grass reduces pine seedling growth (Elliot and White 1987). Cool season grasses reduce pine seedling growth more than warm season grasses because seedling growth coincides with the earlier season growth of the cool season tree species. Therefore, less grass will favor more trees because seed germination and seedling growth are enhanced as well as seedlings survival because fuel levels are reduced.

Tree ring analysis has been widely used to assess the frequency of presettlement fires and tree recruitment. The study of tree rings was developed at the Tree Ring Labatory, University of Arizona. Established in 1937, this is the world's foremost tree ring facility for climate reconstruction, fire history and stand age structure (Douglass 1944). Recent tree ring analysis has identified variable weather patterns as an additional variable leading to pine increase. Working with tree rings from the Navajo Indian Reservation, Savage and Swetnam (1990) showed decreased fire frequencies following increased livestock grazing beginning in 1980, but pine increase did not occur until 1910-1930 when unusually wet years coincided with the fire-free period. Current efforts to reintroduce fire are hindered because the increased pine cover has created a heavy, vertical stacking of fuel that will result in serious crown fires rather than the cooler ground fires than probably existed before the increase in tree density and cover (Covington and Moore 1994).

Evidence from packrat middens suggest that this area supported mixed conifer vegetation more than 18,000 years ago, and that ponderosa pine arrived about 8-10,000 years ago from areas to the south and southeast (Thompson 1988). In fact, in the last 10,000 years, the extent of ponderosa pine has increased from a very isolated distribution to become of the most widespread pines in North America.

Mixed Conifer Forest

Mixed conifer forest occupy approximately 2.5 million acres above ponderosa pine forests in northern and eastern Arizona (Fig. 5) and on the higher sky islands in the southeastern portion of the state (Spencer 1966). One of these sky islands has achieved considerably notoriety as environmentalists and a University of Arizona-led consortium have clashed over the effects of the under-construction Mt. Graham Observatory and attendant loss of mixed conifer forest on the survival of the isolated and endangered Mt. Graham red squirrel *(Tamiasciurus hudsonicus grahamensis)* population (Turbak 1993). Mixed conifer forests, which occurred at much lower eleva-

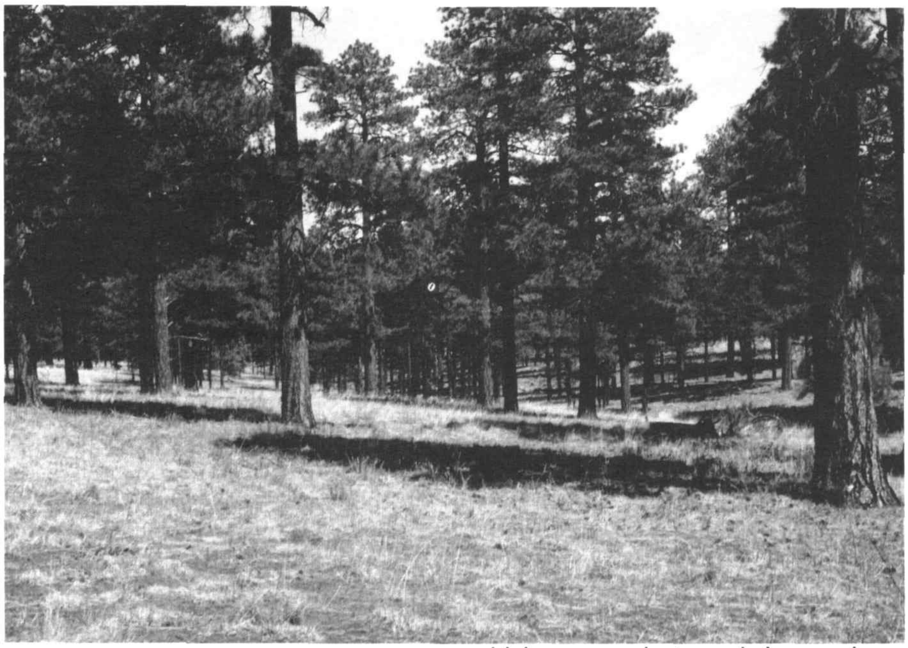

Fig. 4. *Ponderosa Pine Forest vegetation near Flagstaff, Arizona is dominated by pine trees with blue grama and squirreltail grasses in the understory.*

tion as early as 10,000 years ago (Thompson 1988), may not continue to persist on some mountain tops if projections of warmer climates are realized.

Annual precipitation in the mixed conifer forest ranges between 12-16 inches with half or more falling during July through September. Because mixed conifer forests occur at higher elevations, much of the winter precipitation falls as snow. These forests are uniformly cold with nighttime freezing temperatures beginning mid-September and continuing into May (Brown 1982).

Higher elevation mixed conifer forests are dominated by Engelmann spruce (*Picea engelmannii* Perry), and corkbark fir (*Abies lasiocarpa* var. *arizonica* (Merriam) Lemm.) (Embry and Gottfried 1917). Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), and the largest native tree in Arizona (sometimes exceeding 51 inches in diameter and 170 feet in height, Little 1950) occurs in mixtures with blue spruce (*Picea pungens* Engelm.), southwestern white pine (*Pinus strobiformis* Engelm.), white fir (*Abies concolor* (Gord. & Glend.) Lindl.), and ponderosa pine. Fire stimulates sprouting of quaking aspen (*Populus tremuloides* Michx.) in mixed conifer forests and repeated fires result in persistence of quaking aspen stands.

Mixed conifer forests typically have dense overstory canopies with little or no herbaceous vegetation occurring beneath the canopy (Pase 1966). Exceptions occur where disturbances have opened the canopy (fire or timber harvest), beneath quaking aspen stands, or where soils favor the dense herbaceous of mountain meadows. Among the species that do occur in the mixed conifer type are pine dropseed, several bromes, and fescues (*Bromus* spp. and *Festuca* spp.) , rushes, sedges, (*Juncus* spp. and *Carex* spp.) pine dropseed (*Blepharoneuron tricholepis* (Torr.) Nash), numerous forbs, and shrubs such as Fendler ceanothus (*Ceanothus fendleri* Gray), and bearberry manzanita (*Arctostaphylos uva-ursi* (L.) Spreng.).

Mixed conifer forests are a valued resource for their recreational and wildlife values. These forests are used extensively for winter sports and also support a large portion of Arizona's cold water fishery including several streams supporting endangered native Arizona trout. The Merriam elk *(Cervus elphus merriami)* which once dominated the White Mountains of Arizona is now extinct. Populations of Rocky Mountain elk *(Cervus elphus)*, which once were restricted to a much smaller range, have increased dramatically (from 10,000 elk in 1980 to over 30,000 in 1990) and now present a challenge to managers of this and adjacent ecosystems (Brown 1982, Arizona Game and Fish Dept. 1992).

Riparian Forests

Riparian vegetation occurs on 0.25 million acres in Arizona along drainages and/or floodplains that traverse the entire state (Szaro 1989). The ecological and aesthetic importance of this vegetation type is far out of proportion to its relative area, particularly in arid and semi-arid habitats. Carothers and Johnson (1975), for instance demonstrated the importance of riparian vegetation as habitat for breeding birds. The discipline of landscape ecology has emphasized the importance of streams and their associated vegetation as corridors facilitating movement of terrestrial plants and animals across the landscape (Forman and Gordon 1986).

Szaro (1989) provided a detailed classification of riparian communities in the Southwest. Forest communities above 6,500 feet in elevation are dominated by mixed conifer species including big tooth maple (*Acer grandidentatum* Nutt), white fir, blue spruce, and narrow-leaf cottonwood (*Populus angustifolia* James). In the ponderosa pine zone, riparian forests are often dominated by box elder (*Acer negundo* L. var. *interius* (Britt.) Sarg.) and alder (*Alnus oblingofolia* Torr.). Below this, extending through chaparral and grassland into the desert, black walnut (*Juglans major* (Torr.) Heller), Arizona sycamore (*Platanus wrightii* Wats.), velvet ash (*Fraxinus velutina* Torr.), and Fremont cottonwood (*Populus fremontii* Wats.) become major species. The lowest elevation riparian communities traverse desert vegetation and are dominated by mesquite, willows (*Salix* spp.), and the introduced salt cedar (*Tamarix pentanda* Pall.). Other riparian communities are dominated by shrubs including alders and willows at the higher elevations and burro bush (*Hymonoclea monogyra* T. & G.) at the lower elevations.

Because of the uniqueness of riparian vegetation, concern has arisen concerning loss or degradation of these ecosystems (Stromberg 1993a,b). Ohmart et al. (1977) reported that over 90% of riparian vegetation along a small portion of the lower Colorado river had been either lost or degraded. While one cannot extrapolate this percentage to the remainder of Arizona's riparian systems, considerable habitat has been lost and/or degraded and plans once existed to remove riparian vegetation from very large portions of Arizona's rivers to reduce evapotranspiration and increase water delivery downstream (Pacific Southwest Inter-Agency Committee 1969).

Intensive livestock grazing has been identified as a major factor in the degradation of western riparian systems (Ames 1977; Davis 1977; Martin 1979; Thomas et al. 1979). Szaro (1989), in a study of southwestern riparian vegetation, reported that virtually all riparian systems were grazed, the only exception being unique topographic or ownership situations. Many studies have reported adverse effects of cattle grazing and recovery when grazing is modified (Ames 1977; Knopf and Cannon 1982; Taylor 1986; Winegar 1977). The Environmental Protection Agency (Chaney et al. 1993) recently described management to mitigate the effects of livestock. However, the most serious challenge to grazing may come from proposals to protect the habitat of the endangered willow flycatcher (*Empidonax traillii extimus)* (Endangered Species Technical Bulletin 1993). These proposals, if enacted, will potentially eliminate grazing on many southwestern ranges adjacent to riparian forests providing habitat for this neotropical species.

Riparian forests, however, have been influenced by several factors in addition to grazing. These forests originally developed along free-flowing streams under the seasonal influence of flooding (Brady et al. 1985; Fenner et al. 1985; Stromberg et al. 1991). The construction of dams and regulation of downstream flows have significantly changed the riparian environment leading to inevitable long-term and possible major changes in the associated riparian vegetation (Nilsson 1982; Petts 1984; Stromberg et al. 1991; Warner 1984).

Recreation has also proven to be a significant factor affecting both riparian vegetation and soils (Manning 1979). Off-road vehicles have been particularly implicated in degradation of streambanks as well as the stream channel itself (Johnson and Carothers 1982). These disturbance factors, along with the outright elimination of riparian communities for homesites and agriculture have made this one of the most intensely impacted Arizona ecosystems.

Arizona continues to provide ecologists with an incredibility rich and diverse laboratory for understanding ecosystem dynamics. The work of pioneer ecologists including Merriam and Shreve, the establishment of some of the world's earliest long-term research areas, and the development of sophisticated methods for documenting ecological change, including packrat midden analysis, dendrochronology, and stable isotope carbon analysis has given the ecological community a unique and important window for observing ecosystem change over time. Arizona's ecosystems have not only shown dramatic change since the Pleistocene, they continue to illustrate the change inherent in ecosystem dynamics. A plethora of factors from introduction of exotic species in Arizona's deserts and grasslands to the challenges of fire management in shrublands and forests to the management of endangered species and habitats (including riparian forests) continue to provide fertile ground for ecologists to work in the Lemmon's resolute tradition.

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