Ecology of Piñon-Juniper Vegetation in the Southwest and Great Basin

Rex D. Pieper[1]

Abstract—*Piñon-juniper vegetation is conspicuous in foothills surrounding most mountain ranges in the Great Basin and the Southwest. Utah has the largest percentage of piñon-juniper vegetation, followed by New Mexico, Nevada, Arizona, and Colorado. Although piñon-juniper stands may appear to be similar, the vegetation component varies. The most abundant junipers are* Juniperus deppeana, J. monosperma, J. osteosperma, *and* J. scopulorum. *The piñons are* Pinus edulis *in the Southwest and* P. monophylla *in the Great Basin. At most locations the tree layer has 1 to 3 species while the understory is also composed of only a few species. Heavy livestock grazing, tree cutting, reduction of fire frequency and intensity, large-scale control programs, and periodic drought have influenced these woodlands over the past 150 years. Generally woodlands have increased at the expense of grasslands, but there is some debate about the nature of the increase—whether it represents encroachment into grasslands or reoccupation of former woodland sites. Several successional models may be applied to the piñon-juniper woodlands, including Clementsian linear succession, state and transition approaches, and cusp models.*

Introduction

Piñon-juniper vegetation is widely distributed in the West and easily recognized by the size of the tree layer. Utah has the highest percentage of woodlands followed by New Mexico, Nevada, Arizona, and Colorado (figure 1). Woodlands in the northwestern U.S. are represented by juniper woodlands and lack pine representatives.

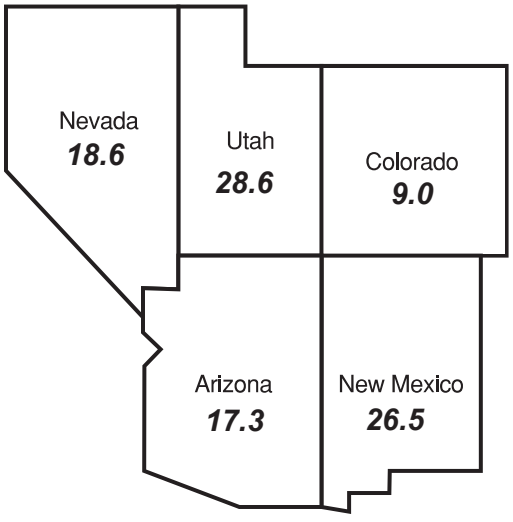

Figure 1—Percent of state occupied by piñon–juniper vegetation (from West and others 1975).

In: Gottfried, Gerald J.; Shaw, John D.; Ford, Paulette L., compilers. 2008. Ecology, management, and restoration of piñon-juniper and ponderosa pine ecosystems: combined proceedings of the 2005 St. George, Utah and 2006 Albuquerque, New Mexico workshops. Proceedings RMRS-P-51. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

[1] *Professor Emeritus of Range Science, Department of Animal and Range Sciences, New Mexico State University, Las Cruces, NM.*

Several classifications of these pigmy forests have been published. Donart and others (1978) recognized a piñon-juniper series as well as a juniper-piñon series; Dick-Peddie (1993) listed a juniper savanna with three series: a oneseed juniper series, a oneseed / Rocky Mountain juniper series, and a Utah juniper series. West and Young (2000) lumped all these types into piñon-juniper woodlands within nine ecological provinces.

Interest in the piñon-juniper woodlands has increased substantially in the last 36 years as evidenced by major symposia presented and proceedings published during that period (table 1).

Vegetational Composition

Ecological provinces listed by West and Young (2000) for piñon-juniper woodlands in the Western United States include Colorado Plateau, Great Basin, northern Rockies, southern Rockies and the Mogollon Rim. Within these woodlands, the following juniper species are common: western juniper (*J. occidentalis*), Utah juniper (*J. osteosperma*), Rocky Mountain juniper (*J. scopulorum*), oneseed juniper (*J. monosperma*), alligator juniper (*J. deppeana*) and redberry juniper (*J. coahuilensis*). The pine species are Rocky Mountain pine (*P. edulis*), singleleaf pine (*P. monophylla*), and Mexican pinyon pine (*P. cembroides*). Many of these tree species overlap in distribution, but form distinct components on a regional basis.

Shrubby and herbaceous layers within the piñon-juniper woodland are more diverse than the tree layer. West and others (1975) listed 31 species in the shrub layer at 20 locations while Gottfried and Pieper (2000) listed 50 species of shrubs in 19 locations (table 2). Forbs were more specific for each location and were more numerous than shrubs and grasses with many annuals (Gottfried and Pieper 2000; West and others 1975). For example, Gottfried and Pieper (2000) listed nearly 200 species of forbs on 19 locations (table 2). Of these only three occurred on more than one location: Louisiana sagewort (*Artemisia ludoviciana*), wholeleaf Indian paintbrush (*Castilleja integra*), and scarlet globemallow (*Sphaeralcea coccinea*). Locations cited by West and others (1975) came mainly from the Great Basin and Intermountain Region while those from Gottfried and Pieper (2000) were mainly from southwestern locations.

Spatial Variation

Fine Scale

Within piñon-juniper woodlands, vegetational patterns are conspicuous under trees as well as in the surrounding open spaces. Arnold (1964) described three distinct zones associated with an individual *J. monosperma* tree in Arizona. Blue

Table 1—Symposia on piñon–juniper ecology.

Location and Host	Year	Pages	Articles	Citation
Logan, UT, Utah State University	1975	196	18	Gifford and Busby (1975)
Santa Fe, NM, U.S. Forest Service	1977	48	12	Aldon and Loring (1977)
Reno, NV, U.S. Forest Service	1987	581	91	Everett (1987)
Santa Fe, NM, N.M. State Land Office	1993	168	38	Aldon and Shaw (1993)
Flagstaff, AZ, U.S. Forest Service	1994	226	35	Shaw and others (1994)
Provo, UT, U.S. Forest Service	1997	441	78	Monsen and Stevens (1999)

Table 2—Common understory shrubs and grasses listed for selected locations in the Western United States

Common Name	Scientific Name	Percent of locations (West and others 1975)	Percent of locations (Gottfried and Pieper 2000)
Shrubs			
Big sagebrush	*Artemisia tridentata*	55	37
Antelope bitterbrush	*Purshia tridentata*	40	32
Gambel oak	*Quercus gambelii*	15	21
Yellow rabbitbrush	*Chrysothamnus viscidiflorus*	30	32
Mormon tea	*Ephedra viridis*	15	16
Grasses			
Squirreltail	*Elymus elymoides*	45	37
Indian ricegrass	*Achnatherum hymenoides*	35	37
Sandberg bluegrass	*Poa secunda*	30	16
Hairy grama	*Bouteloua hirsuta*	15	21
Blue grama	*Bouteloua gracilis*	15	21
Bluebunch wheatgrass	*Pseudoroegneria spicatum*	25	5
Prairie junegrass	*Koeleria macrantha*	15	0

grama was not present next to the bole of the tree, but contributed 0.6% basal cover in the canopy zone and 1.4% in the open space. Similar patterns were noted by Armentrout and Pieper (1988) in New Mexico.

The C_3 grass patterns around individual trees contrast with the pattern for blue grama. Clary and Morrison (1973) found that the biomass of cool-season (C_3) grasses was enhanced by the canopy of alligator juniper (*J. deppeana*) in Arizona (table 3). Similar results were reported by Schott and Pieper (1985) (table 4) and

Table 3—Total herbage and cool-season grass biomass (lb/acre) associated with alligator juniper trees in eastern Arizona (from Clary and Morrison 1973).

Type	Crown zone	Root zone	Open zone
	- - - - - - - - - - - - Biomass- - - - - - - - - - - -		
Total herbage	377	121	147
Grass	350	73	78

Table 4—Percent basal cover of three grass species in relation to position under oneseed juniper trees in the Sacramento Mountains in New Mexico (from Schott and Pieper 1982).

Species	Edge	Middle	Center
Bouteloua gracilis			
North	23.8	16.7	1.4
South	23.1	9.6	1.4
Lycurus setosus			
North	2.2	0.4	0
South	2.4	0.2	0
Pipptochaetium fimbriatum			
North	0	4.0	2.3
South	0	0.3	1.3

Pieper (1990) (figure 2). Direction from the tree bole also influenced cover of blue grama (*Bouteloua gracilis*), piñon ricegrass (*Piptochaetium fimbriatum*), and New Mexico feathergrass (*Muhlenbergia pauciflora*) (table 4) (Schott and Pieper 1985).

Biomass of blue grama is generally negatively associated with tree canopy cover in piñon-juniper woodlands in the Sacramento Mountains of New Mexico. Biomass of C_3 generally increased as canopy cover increased (Pieper 1990).

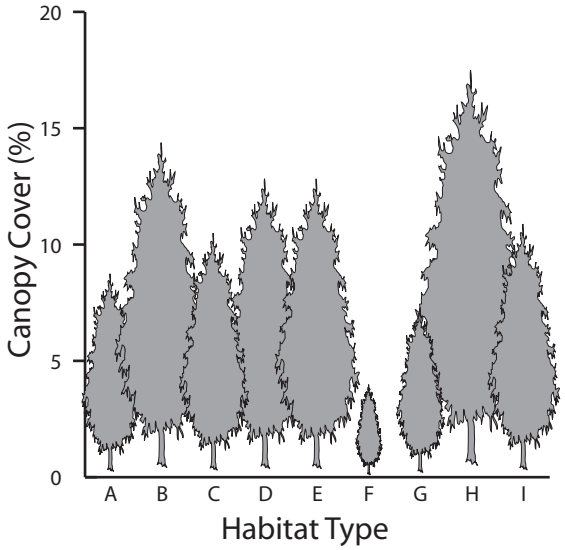

Figure 2—Canopy cover of alligator juniper on different habitat types in western New Mexico (from Hill and others 1990).

Intermediate Scales: Elevation and Aspect

Elevation

Within the woodland, as elevation increases pine abundance generally increases and juniper generally decreases, a pattern exemplified in early studies in northern New Mexico (Woodin and Lindsey 1954). Similar patterns were also shown for the Great Basin (Tueller and others 1979). However, later studies indicate that these patterns may not hold under all circumstances. For example, Kennedy (1983) showed that density of oneseed juniper peaked at intermediate elevations in the Sacramento Mountains in New Mexico. Hill (1990) found that alligator juniper density generally declined with elevation, but tended to level off at intermediate elevations before declining at the lowest elevations.

In southeastern Arizona and northern Mexico, Whittaker and Niering (1965) and Perez (1979) found similar patterns. Mexican pine and alligator juniper increased with elevation from lower positions to intermediate elevation and then declined slightly from intermediate to higher elevations. Undoubtedly many other factors mediate the influence of elevation on the composition of these woodlands as well.

Aspect

Lymbery and Pieper (1983) found that the three tree species in the Sacramento Mountains of New Mexico were distributed on all aspects. Oneseed juniper had a slightly lower canopy cover on xeric southwestern slopes while the highest cover for Rocky Mountain piñon occurred on mesic northwestern aspects. Alligator juniper grew on all aspects, but had slightly higher canopy cover on southwestern slopes.

Regional Scales

West and Young (2000) showed regional differences in tree species within the piñon-juniper woodland, which are also shown by comparisons among various individual studies. Hill and others (1992) identified 10 distinct woodland habitat types in the Gila National Forest in western New Mexico (figure 2), and that the canopy cover of alligator juniper varied from 4 to 18% in these habitat types. Oneseed juniper is distributed largely in central New Mexico with canopy cover as high as 85%, while alligator juniper is more abundant in western New Mexico and Arizona.

Variation in Time

Similar successional patterns were described and diagramed for woodland locations in Colorado, Arizona, and Utah (Arnold and others 1964, Barney and Frischknecht 1974, and Erdman 1976). These diagrams showed that climax woodland communities could be replaced by skeleton forests with sparse understory following fire. Eventually the woodlands would pass through successional stages: annual plants, perennial grass—forbs, shrubby plants, and finally climax juniper or piñon-juniper woodland. Individual species were different for each stage, but they were similar in overall stages. These stages appear similar to many Clementsian linear models, with fire likely to enter at any point in the sequence. An example from Fort Stanton in the central Sacramento Mountains in New Mexico indicated that blue grama grassland became reestablished following severe droughts of the early 1970s, and by 1984 both biomass and composition of blue grama were at pre-drought levels (Pieper and others 1991).

Tress and Klopatek (1987) presented longer time scales for development of piñon-juniper woodlands based on modeling approaches. They showed that understory grasses reached a peak after about 100 years, then declined and plateaued at about 150 years. Shrubs, on the other hand, peaked at about 40 years, then gradually declined and were only minor components after 150 years. Tree canopy cover gradually increased and maintained a maximum canopy cover of about 35% after 180 years. However, these time frames were estimated without major disturbances such as intense fires. Arnold and others (1964) found similar changes following mechanical control treatments in northern Arizona.

Later studies have emphasized the importance of altered fire regimes as mediated by heavy livestock grazing that reduced fine fuels necessary to carry fires. Diagrams showing historical events since European settlement in the 1850s were presented by Allen (1989), Gottfried and others (1995), and West and Van Pelt (1987). These diagrams emphasized the role of heavy livestock grazing that reduced fine fuels and reduced the incidence and intensity of fires. Gottfried and others (1995) stated that "… today most local PJ woodland ecosystems are unstable from a soil perspective, with many moving towards PJ rocklands."

These later analyses suggest that state and transition models (Westoby and others 1989) might be appropriate. However, the review by Iglesias and Kothmann (1997) showed no examples of state and transition diagrams for piñon-juniper woodlands. Figure 3 shows a tentative state and transition model for loamy upland sites with residual soils in the central Sacramento Mountains in New Mexico. In this model, piñon-juniper woodland could be converted to grassland through cutting, other control methods (mechanical, chemical), or intense fire. Grassland dominated by blue grama and Carruth's sagewort (*Artemisia carruthii*) could be changed to herbland dominated by wolfstail (*Lycurus setosus*), broom snakeweed (*Gutierrezia sarothrae*), and showy goldeneye (*Heliomeris multiflora*). Recovery from drought could lead to grassland dominated by blue grama and Carruth sagewort along with many other grasses and forbs, while heavy grazing could tend to increase basal cover of blue grama, creeping muhly, and ring muhly (*Muhlenbergia repens* and *M. torreyi*).

The increase in woody components at the expense of grassland has been noted by several investigators, but interpretations of this change have varied. Krenetsky (1974) resampled several plots in 1964 that had been sampled in 1943 and 1953, and found that canopy cover of oneseed junipers increased under grazed and ungrazed conditions at the expense of grassland in central New Mexico. Miller (1999) used aerial photos to show that woodlands increased in area from 1935 to 1991 at the expense of grasslands on Negrito Creek in western New Mexico. Allred (1996) reported that "…researchers from out of state have suggested a pattern. Ecologists generally assert that piñon and juniper species have either expanded in range or increased in density throughout the West, usually transgressing into adjacent grassland."

Sallach (1986) used photo time sequences to suggest that most of the expansion has been reoccupation of former piñon-juniper sites: "In piñon-juniper woodland, *Pinus edulis* and *Juniperus monosperma* have reestablished on former sites of piñon-juniper woodland. There has not been an extension in area of piñon-juniper woodlands."

It appears that both types of changes have occurred: (1) encroachment onto grassland sites where historic fires tended to limit woody components, and (2) reoccupation of former woodland sites where the trees were removed.

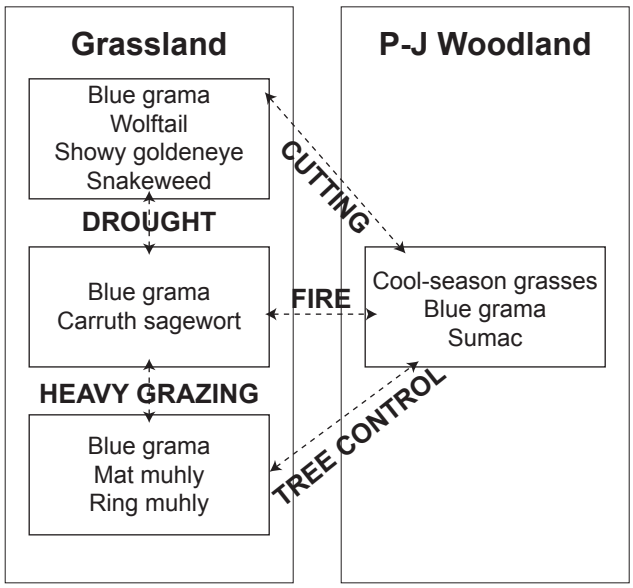

Figure 3—State and transition model for loamy upland ecological sites with residual soils within the central Sacramento Mountains in New Mexico.

References

Aldon, Earl F., and Thomas J. Loring, tech. coords. 1977. Ecology, uses, and management of pinyon-juniper woodlands. Proceedings of the workshop. 1977 March 24–25; Gen. Tech. Rep. RM-39. Fort Collins, CO: U.S. Department of Agriculture. Forest Service. Rocky Mountain Forest and Range Experiment Station. 48 p.

Aldon, Earl F. and David W. Shaw, tech. coords. 1993. Managing pinyon-juniper ecosystems for sustainability and social needs: proceeding of the symposium. Santa Fe, NM. 1993 April 26-30. Gen. Tech. Rep. RM-236. U.S. Department of Agriculture. Forest Service. 169 p.

Allen, Craig D. 1989. Changes in the landscape of the Jemez Mountains, New Mexico. Ph.D. Dissertation. Univ. of Calif. Berkeley, CA. 346 p.

Allred, Kelly W. 1996. Vegetative changes in New Mexico rangelands. In: Herrera, Esteban A., and Laura F. Huenneke, eds. New Mexico's natural heritage: biological diversity in the land of enchantment. New Mexico Journal of Science 36:168-231.

Armentrout, Susan M., and Rex D. Pieper. 1988. Plant distribution surrounding Rocky Mountain pinyon pine and one-seed juniper in south-central New Mexico. Journal of Range Management 41(2):139-143.

Arnold, Joseph F. 1964. Zonation of understory vegetation around a juniper tree. Journal of Range Management 17(1):41-42.

Arnold, Joseph F., Donald A. Jameson, and Elbert H. Reid. 1964. The pinyon-juniper type in Arizona: effect of grazing, fire, and tree control. Prod. Res. Pap. 84. Washington, DC: U.S. Department of Agriculture. 28 p.

Barney, Milo A., and Neil C. Frischknecht. 1974. Vegetation changes following fire in the pinyon-juniper type of west-central Utah. *(Juniperus osteosperma*, *Pinus monophylla*). Journal of Range Management 27(2):91-96.

Clary, Warren P., and Donald C. Morrison. 1973. Large alligator juniper benefits early-spring forage. Journal of Range Management 26(1):70-71.

Dick-Peddie, William A. 1993. New Mexico vegetation past, present, and future. Albuquerque, NM. University of New Mexico Press. 244 p.

Donart, Gary B., Donell Sylvester, and Wayne Hickey. 1978. A vegetation classification system for New Mexico, U.S.A. Proceedings of the First International Rangeland Congress. Denver, CO. Society for Range Management:488-490.

Erdman, James A. 1970. Pinyon-juniper succession after fire on residual soils of Mesa Verde, Colorado. Provo, UT. Brigham Young University. Science Bulletin Biological Series 11:1-24.

Everett, Richard L., compiler. 1987. Proceedings, pinyon-juniper conference. 1986. January 13-16 1986. Reno. NV. Gen. Tech. Rep. INT-215. Ogden UT: U.S. Forest Service. Intermountain Research Station. 581 p.

Gifford, Gerald, and Frank E. Busby, eds. 1975. The pinyon-juniper ecosystem: a symposium. Logan, UT., Utah State University. 166 p.

Gottfried, Gerald J., Thomas. W. Swetnam, Craig D. Allen, Julio Betancourt, and Alice L. Chung-MacCaubrey. 1995. Pinyon-juniper woodlands. In: Deborah. M. Finch and. Joseph A. Tainter, tech. eds. 1995. Ecology, diversity, and sustainability of the Middle Rio Grande Basin. Gen. Tech. Rep. RM-GTR-268. Fort Collins, CO. U.S. Department of Agriculture, Forest Service. Rocky Mountain Forest and Range Experiment Station:95-132.

Gottfried, Gerald J., and Rex D. Pieper. 2000. Pinyon-juniper rangelands. In: Jemison, Roy and Carol Raish, eds. Livestock management in the American Southwest ecology, society and economics. Amsterdam. Elsevier:153-211.

Hill, Alison. 1990. Ecology and classification on the pinyon-juniper woodlands in western New Mexico. Ph. D. Dissertation. Las Cruces, NM. New Mexico State University. 176 p.

Hill Alison, Rex D. Pieper, and G. Morris Southward. 1992. Habitat-type classification of the piñon-juniper woodlands in western New Mexico. Bull. 766. Las Cruces, NM. New Mex. State University Agricultural Experiment Station. 58 p.

Iglesias, Ricardo M. Rodriguez and Mort M. Kothmann. 1997. Structure and causes of vegetation change in state and transition model applications. Journal of Range Management 50 (4):399-408.

Kennedy, Kathryn L. 1983. A habitat type classification for the pinyon-juniper woodlands of the Lincoln National Forest. Las Cruces, NM. M.S. Thesis. New Mexico State University. 58 p.

Krenetsky, J. C. 1971. Effects of controlled grazing and complete protection on New Mexico range lands after twenty-five years. Albuquerque, NM. Ph. D. Dissertation. University of New Mexico. 166 p.

Lymbery, Gordon A., and Rex D. Pieper. 1983. Ecology of pinyon-juniper vegetation in southcentral New Mexico. Las Cruces, NM. New Mexico State University Agriculture Experiment Station Bulletin 698. 48 p.

Miller, Mark E. 1999. Use of historic aerial photographs to study vegetation change in the Negrito Creek watershed southwestern New Mexico. The Southwestern Naturalist 44(2):121-137.

Monsen, Steven B., and Richard Stevens, compilers. 1999. Proceedings: ecology and management of pinyon-juniper communities within the interior West. 1997 Sept. 15-18. Provo, UT. Proc. RMRS-P-9 Ogden UT. U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station. 411 p.

Perez-Garcia, Alberto. 1978. Ecology of oak communities on the eastern foothills of the Sierra Madre Occidental in Chihuahua. Las Cruces, NM. Ph. D. Dissertation. New Mexico State University. 240 p.

Pieper, Rex D., Eugene E. Parker, Gary B. Donart, Joe D. Wallace and Jimmy D. Wright. 1991. Cattle and vegetation response to four-pasture rotation and continuous grazing systems. Las Cruces, NM. New Mexico State University Agricultural Experiment Station Bulletin 756. 23 p.

Pieper, Rex D. 1990. Overstory-understory relations in pinyon-juniper woodlands in New Mexico. Journal of Range Management 43(5):413-415.

Sallach, Barbara K. 1986. Vegetation changes in New Mexico documented by repeat photography. Las Cruces, NM. M. S. Thesis. New Mexico State University. 67 p.

Schott, Martin R., and Rex D. Pieper. 1985. Influence of canopy characteristics on one-seed juniper on understory grasses. Journal of Range Management 38(4):328-331.

Shaw, Douglas, Earl F. Aldon, and Carol LoSapio, tech. coords. 1994. August 8-12. Desired future conditions for piñon-juniper ecosystems. Flagstaff, AZ. Gen. Tech. Rep. RM-258. Fort Collins, CO. U.S. Department of Agriculture. Forest Service, Rocky Mountain Forest and Range Experiment Station. 226 p.

Tress, James A. Jr., and Jeffrey Klopatek. 1987. Successional changes in community structure of pinyon-juniper woodlands in north-central Arizona. In: Everett, Richard L., compiler. Reno, NV. January 13-16, 1986. Proceedings, pinyon-juniper conference. Gen. Tech. Rep. INT-215. U.S. Department of Agriculture, Forest Service:80-85.

Tueller, Paul T., C. D. Beeson, Robin J. Tausch, Neil E. West, and Kenneth H. Rea. 1979. Pinyon-juniper woodlands of the Great Basin: distribution, flora, vegetal cover. Res. Pap. INT-229. Ogden UT. U.S. Department of Agriculture, Forest Service. 68 p.

West, Neil E., Kenneth H. Rea, and Robin J. Tausch. 1975. Basic synecological relationships in Juniper-pinyon woodlands. In: Gifford, Gerald F., and Frank E. Busby. Eds. The pinyon-juniper ecosystem: a symposium. Logan, UT. College of Natural Resources, Utah StateUniversity:41-53.

West, Neil, and James A. Young. 2000. Intermountain valleys and lower mountain slopes. In: Barbour, Michael G., and William D. Billings, eds. North American terrestrial vegetation. 2nd ed. United Kingdom. Cambridge Univ. Press:255-284.

West, Neil E., and Nicholas Van Pelt. 1987. Successional patterns in pinyon-juniper woodlands. In: Everett, Richard L. compiler. Proceedings, Pinyon-juniper woodlands. 1986 January 13-16; Reno, NV. Gen. Tech. Rep. INT-215. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Research Station:43-52.

Westoby, Mark, Brian Walker, and Imanuel Noy-Meir. 1989. Opportunistic management for rangelands not at equilibrium. Journal of Range Management 42(4):266–274.

Whittaker, Robert H., and William A. Niering. 1965. Vegetation of the Santa Catalina Mountains, Arizona. Ecology 46(3):473-489.

Woodin H. E., and Alton A. Lindsey. 1954. Juniper-pinyon east of the continental divide analyzed by the line-strip method. Ecology 35(5):473-489.