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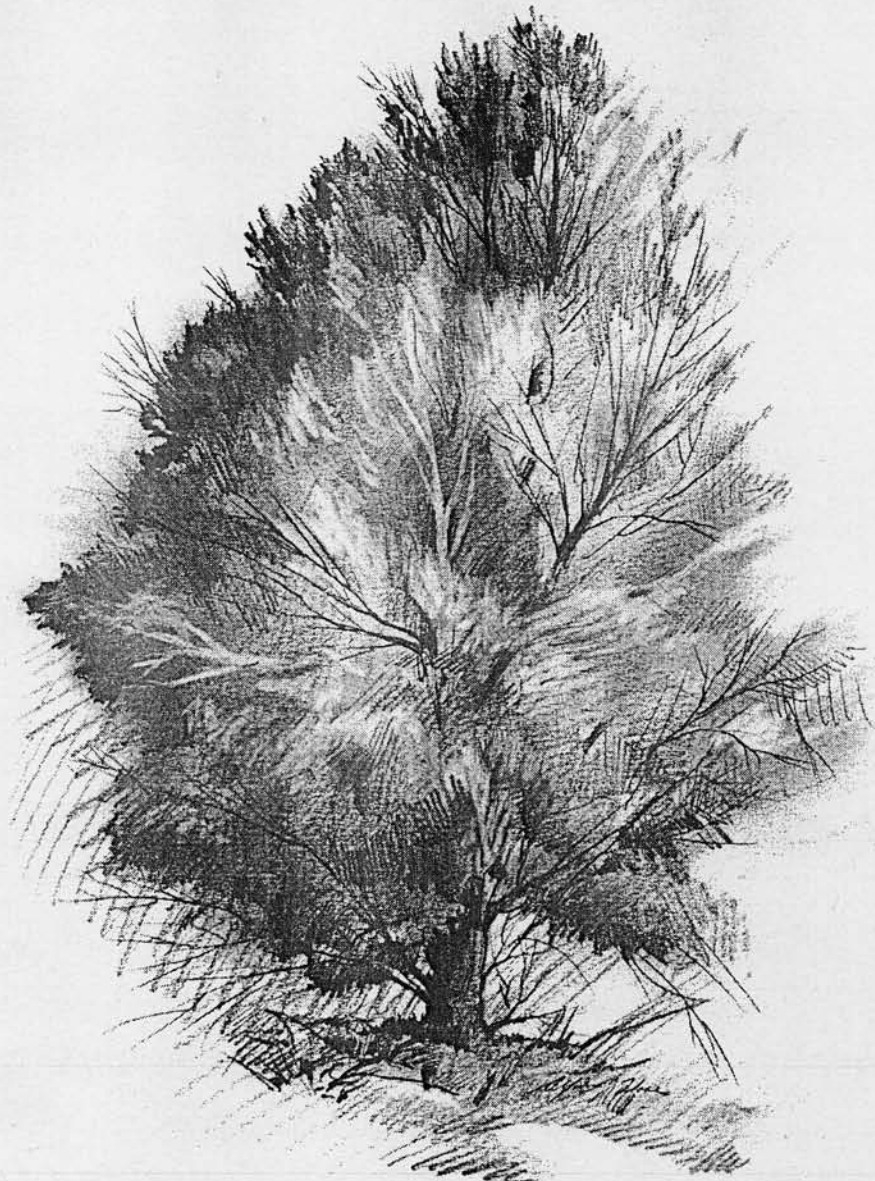
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Proceedings: Ecology and Management of Pinyon-Juniper Communities Within the Interior West



Sustaining and Restoring a Diverse Ecosystem

Conversion of Shrub Steppe to Juniper Woodland

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Abstract—Juniper woodlands are frequently treated generically in management, wildlife studies, and environmental issues. Western juniper grows on a broad variety of soils and terrain, creating a high degree of spatial variability in stand structure and function. Stand heterogeneity can also be attributed to temporal or successional differences in shrub steppe conversion to juniper woodlands. During conversion a threshold is crossed which moves the shrub steppe community to a new steady state driven by different ecological processes. It is important to recognize both spatial and temporal heterogeneity when evaluating habitat suitability, predicting potential resource problems related to stand development, developing management plans, and setting priorities.

Over 8 million acres of sagebrush steppe are in various stages of conversion to western juniper woodlands (*Juniperus occidentalis* spp. *occidentalis*) in the semi-arid Inter-mountain Northwest (Miller and Wigand 1994). The rapid conversion of shrub steppe to western juniper woodlands (Burkhardt and Tisdale 1976, Young and Evans 1981, Miller and Rose 1995) has occurred across a wide variety of sagebrush communities, soils, and topography since the 1880s. The combination of spatial and temporal diversity creates a vast array of structurally different juniper communities, many of which are changing. Juniper woodland function and structure changes across different soils, landscape positions, and stages of development. During woodland development, low densities of trees in the early phases of encroachment add structural heterogeneity to shrub steppe community types. However, as woodlands continue to develop, tree function changes with size, distribution, and density. As woodland function and structure shift across varying landscapes and stages of development there are significant effects on community composition, diversity, and associated soils. Wildlife habitat suitability is also altered across time and space.

Juniper woodlands have often been treated generically during the development of management plans, defining wildlife values, and debates relating to the benefits or problems of these communities. The illusion of a homogeneous landscape is created as tree canopies close. The majority of wildlife studies and inventories in the Inter-mountain West have not considered the wide variation of structure and function of woodlands across community types and in different successional stages. Spatial and temporal heterogeneity generally have not been taken into account when considering the impacts of woodland development on erosion, loss of understory, or plant diversity. It is very important to identify the community type, stage of woodland development, and thresholds for developing management plans, setting priorities, determining the best management tools to use, evaluating wildlife habitat values, and determining the effects of no action.

This paper will present preliminary results and discuss several concepts relating to the conversion of shrub steppe communities to western juniper woodlands. Specific objectives are to: (1) describe the different phases of shrub steppe conversion to juniper woodland, (2) discuss thresholds that are crossed during the conversion of shrub steppe to woodland, and (3) describe the effects of spatial variability on woodland development.

Study Area

The conversion of shrub steppe to juniper woodlands was studied in both the High Desert and Klamath ecological provinces of eastern Oregon and northeastern California (fig. 1). Climate is cool and semiarid, characteristic of the northern Great Basin. Annual precipitation in the western juniper woodland zone typically ranges from 12 to 16 inches. Most of the moisture is received as snow in November, December, and January and as rain in March through June. Summers are usually dry. Soils in these two provinces are primarily derived from igneous materials such as basalt, andesite and rhyolite. The largest area of woodland conversion is in mountain big sagebrush (*Artemisia tridentata* spp. *vaseyana*) and low sagebrush (*A. arbuscula*) steppe communities. However, western juniper encroachment also occurs in basin big sagebrush (*A. tridentata* spp. *tridentata*), bitterbrush (*Purshia tridentata*), mountain mahogany (*Cercocarpus ledifolius*), aspen (*Populus tremuloides*), and riparian communities.

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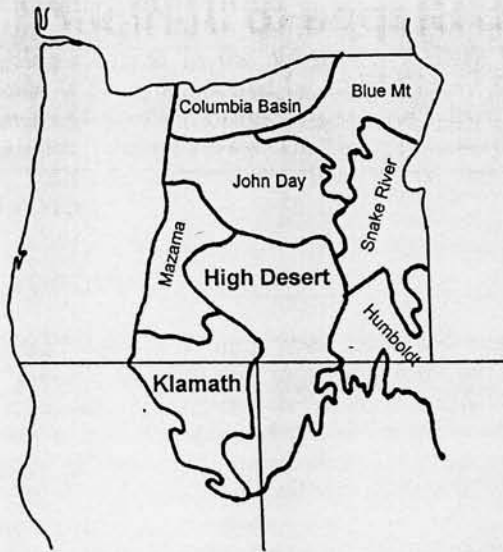


Figure 1—Ecological provinces in the Intermountain northwest region where western juniper occurs (derived from Anderson 1956 and Bailey et al. 1994).

Methods

Plant community composition, and soils were measured in a 160 macroplots, 60 x 45 m, across the two ecological provinces. We collected a representative sample of community types characterizing this region within the western juniper belt in different stages of woodland conversion. Juniper cover was measured along three 60 m line intercepts within each macroplot. Tree density was recorded in three 60 x 6 m rectangular plots. Shrub cover was measured along three 30 m line intercepts and density determined in 30 x 2 m plots. Both density and cover of herbaceous species were recorded in 0.20 m² plots placed at 3 m increments along the three 60 m transects. Soils were described for each macroplot and samples collected for textural analysis. Elevation, aspect, and slope were also measured.

Discussion

Temporal Change

Several thresholds may be crossed as juniper woodlands develop. Once a threshold is crossed the probability of a community returning to a previous state is very low. The conceptual model in figure 2 illustrates the conversion of shrub steppe communities to juniper woodland in the absence of fire. The perennial forb-grassland and shrub steppe communities are a fire driven system. During the early phases of woodland development, transition is reversible.

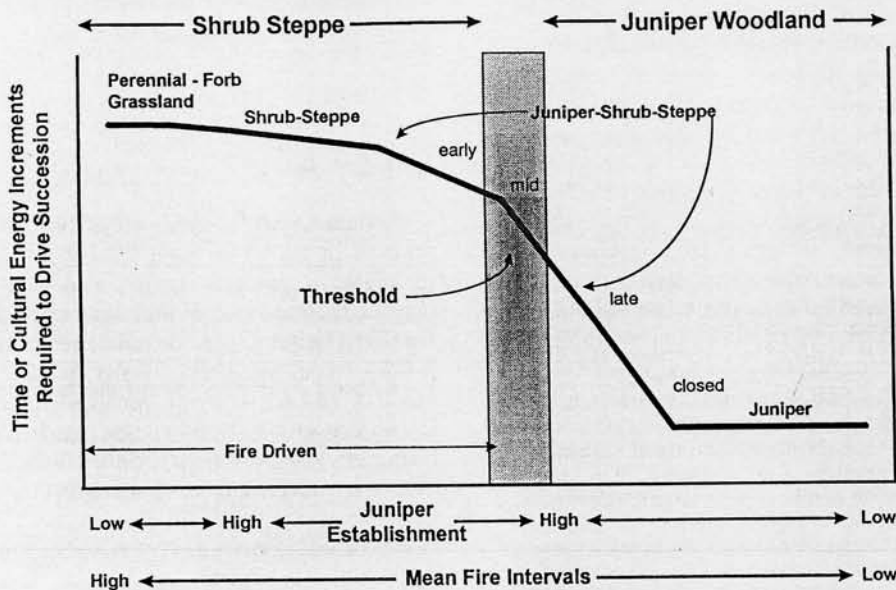


Figure 2—Conceptual diagram of changes in a shrub steppe community in the absence of fire (modeled after Archer 1989). In the absence of fire the abundance of shrubs decline as juniper trees gain dominance. The threshold has been crossed when understory fuels drop to a level where fire is unlikely to carry through the stand or generate enough heat to kill trees > 10 ft tall. The probability of the woodland crossing the threshold and reverting back to shrub steppe is very low in the absence of a major disturbance or very costly inputs.

However, by mid to late stages of transition a threshold is crossed where the reversal to shrub steppe communities is unlikely. Shrubs begin dying out as woodlands approach mid development, in mountain big sagebrush community types. As shrubs decline in the understory the probability of a fire event intense enough to kill large juniper trees rapidly declines.

Presettlement fire return intervals in mountain big sagebrush were frequent enough to maintain shrub steppe community types. Fire return intervals in these communities usually ranged between 10 and 25 years (Houston 1973, Burkhardt and Tisdale 1976, Martin and Johnson 1979, Miller and Rose in press). Trees less than 10 ft tall are easily killed by fire (Bunting 1984). It usually requires 40 to 50 years for a western juniper to attain this height in mountain big sagebrush community types (Miller and Rose 1995). The maximum hazard function (100 percent probability that a fire will occur within a defined time period) prior to 1880 was 45 years in a mountain big sagebrush community type in south central Oregon (Miller, unpublished data). However, the maximum hazard function for many newly formed juniper woodlands is 1,000 years. In low sagebrush-Sandberg bluegrass (*Poa sandbergii*) community types tree establishment and growth rates are limited in the shallow heavy clay soils. One fire every 100 to 150 years were adequate to maintain a widely scattered stand of juniper in these communities.

The state of woodland transition can be identified by structural characteristics of the woodland (table 1). Tree canopy cover and density alone have limited value as indicators of stand closure (the point where the site is fully occupied by juniper) since tree abundance is highly variable across community types. Sites with naturally low productivity will reach stand closure at lower juniper canopy cover and density than a more productive site. However, tree growth characteristics and shrub vigor are good indicators of the

early stages of stand closure. Leader growth on dominant and understory trees is probably the best indicator for degree of stand closure for the site. The reduction in leader growth on trees less than 10 ft tall is due to intra-specific competition from larger neighboring trees. Prior to stand closure shrubs begin dying near the base and directly adjacent to large juniper trees. Shrubs begin thinning in the inner space during the early phases of stand closure (late-mid to early late woodland development), about the same time as understory tree leader growth becomes suppressed. At this stage of juniper woodland development shrub steppe community characteristics in the understory quickly change. During the later stages of woodland development tree recruitment declines due to changes in seed production and community structure. As intra-specific competition between trees increases, seed production declines and the ratio of male:female trees increases. This reduces seed rain from within the stand although birds, the primary seed dispersers of juniper berries, can easily bring in seed from outside sources. However, micro sites provided by shrubs for juniper seedling establishment decline during the later stages of woodland development. Shrubs are an important structural component for the germination and establishment of juniper seedlings (Miller and Rose 1995).

Crossing the threshold in juniper woodlands results in a significant reduction in the role of fire. On many sites, crossing the threshold may result in a loss of native herbaceous species (fig. 3), the potential loss of surface soil, and the loss of mast crops for wildlife. However, site factors such as soil depth and texture, the presence of shallow hardpans, slope, and aspect influence the effects of juniper competition on understory vegetation and soils. Grazing and fire suppression are the two primary management activities that have influenced junipers' interaction with the herbaceous understory. Below about 5,000 feet in elevation, poor grazing management can hasten the abundance of exotic

Table 1—Structural characteristics that change during the conversion of mountain big sagebrush community types to fully developed western juniper woodlands.

Characteristics (Post settlement stands)	Early	Mid	Late	Closed
Leader growth (Dominant trees)	Good terminal and lateral growth	Good terminal and lateral growth	Good terminal growth, reduced lateral growth	Good to reduced terminal growth, lateral growth absent
Tree Canopy	Open, actively expanding cover ≤ 5 percent	Actively expanding, cover 6 to 20 percent	Canopy expansion greatly reduced, cover 21-35 percent	Canopy expansion stabilized, cover > 35 percent
Crown Lift (Dominant Trees)	Absent	Absent	Lower limbs beginning to die (for productive sites)	Lower limbs dead (for productive sites)
Potential berry production	Low	Moderate to High	Low to Moderate	Nearly absent
Potential Tree Recruitment	High	High	Reduced	Nearly absent
Growth (Understory trees)	Good terminal and lateral growth	Good terminal and lateral growth	Greatly reduced terminal and lateral growth; reduced ring growth	Leader growth absent, some mortality, limited ring growth
Shrub Layer	Intact	Nearly intact to dying canopies around dominant trees	≥ 40 percent dead	≥ 85 percent dead

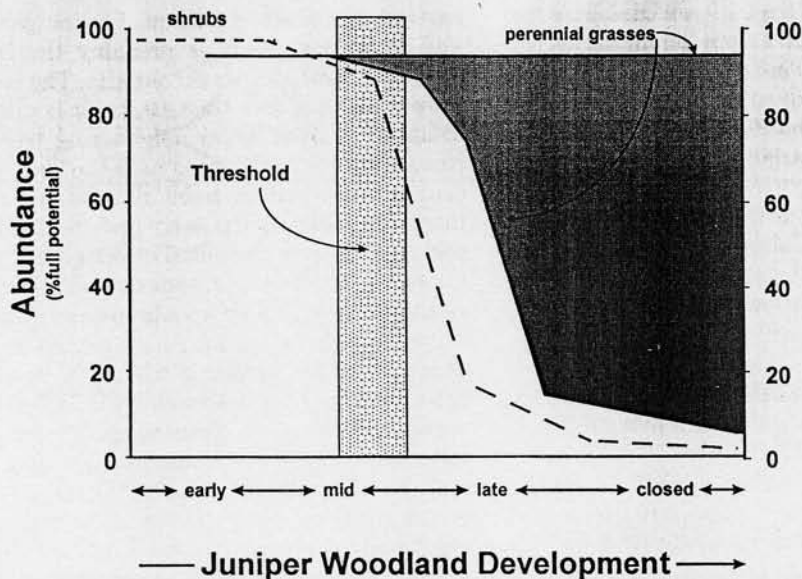


Figure 3—Conceptual model illustrating the change in abundance of perennial grasses and shrubs during the conversion of shrub steppe to juniper woodland. The affect of juniper woodland succession on grass abundance is variable, dependent upon site factors (soils, aspect, etc.). The shaded area between the perennial grass line, during mid to closed stages of woodland development, illustrate the different levels of grass abundance that occurs across different sites.

annuals. Above 5,000 feet exotic annuals are less abundant, but poor grazing management can reduce herbaceous cover and increase the amount of bare ground. The loss of soil during woodland conversion is particularly acute on south slopes that have been improperly grazed.

As woodlands develop, the threshold of habitat suitability for certain wildlife species is also crossed. Horned larks, vesper sparrows, brewers sparrows, sage thrashers, and sage grouse decline during the mid to late stages of woodland development (Eastern Oregon Agricultural Research Center unpublished data). The lowest abundance of mountain bluebirds occurred in closed juniper stands in contrast to the highest counts that occurred in open old growth juniper woodlands, and sagebrush steppe communities adjacent to old growth woodlands.

Spatial

Western juniper occurs across a wide array of soils within the two provinces including Durargids and Haplargids commonly characterizing the low sage community types, and Druixerolls, Argixerolls and Haploxerolls in the mountain big sagebrush community types. Soil suborders vary from aridic, lithic, typic and pachic and soil temperature regimes range from mesic to frigid. Soil textures vary from 80 percent clay content on juniper low sage tablelands to 80 percent sand in the aeolian sand region. Soil depths vary from zero on fractured rock to deep Haploxerolls commonly found on mountain big sagebrush/snowberry (*Symphoricarpos oreophilis*)/Columbia needlegrass and aspen community types.

Western juniper occurs across a large number of plant community types in the High Desert and Klamath ecological provinces (table 2). Plant community structure in fully developed woodlands varies across and within community types. Tree canopy cover measured within community types for fully developed woodlands ranged between 20 percent in low sagebrush/Sandberg bluegrass to over 90 percent in aspen community types (fig. 4). Vertical lines in figure 4 are anticipated ranges of maximum juniper cover within different community types based upon our observations. Tree numbers were also highly variable in fully developed woodlands across community types (fig. 5). Density of mature trees varied from 50 per acre in low sagebrush to over 300 per acre in mountain big sagebrush/Columbia needlegrass. In mountain big sagebrush community types with clay to clay loam soils and argillic horizons, average densities of mature trees typically ranged between 120 to 200 per acre. Tree densities were usually over 250 per acre on deep loams with weak to absent argillic horizons. These productive community types are typically positioned on northerly aspects. Densities of mature juniper trees in aspen stands converted to juniper woodland were over 700 per acre.

We are currently analyzing the herbaceous cover data across the plots to determine the relationship of juniper and environmental variables on understory composition and structure. A consistent response across all plots is the decline in mountain big sagebrush with the increase in western juniper (fig. 3). However, preliminary results indicate the response of perennial grass and forb cover to juniper cover is inconsistent across and within community types. The shaded area in Figure 3 represents the full range of

Table 2—Plant community types commonly invaded by western juniper in the High Desert and Klamath ecological provinces in southeastern Oregon and northeastern California.

Dominant shrub	Co-dominant shrub	Dominant grass
Low sagebrush		Sandberg bluegrass
Low sagebrush		Bluebunch wheatgrass
Low sagebrush		Idaho fescue
Basin big sagebrush		Basin wildrye
Basin big sagebrush		Thurber needlegrass
Mountain big sagebrush		Thurber needlegrass
Mountain big sagebrush		Bluebunch wheatgrass
Mountain big sagebrush		Idaho fescue
Mountain big sagebrush		Columbia needlegrass
Mountain big sagebrush	Bitterbrush	Thurber needlegrass
Mountain big sagebrush	Bitterbrush	Bluebunch wheatgrass
Mountain big sagebrush	Bitterbrush	Idaho fescue
Mountain big sagebrush	Snowberry	Idaho fescue
Mountain big sagebrush	Snowberry	Columbia needlegrass
Curleaf mountain mahogany		Idaho fescue
Aspen		

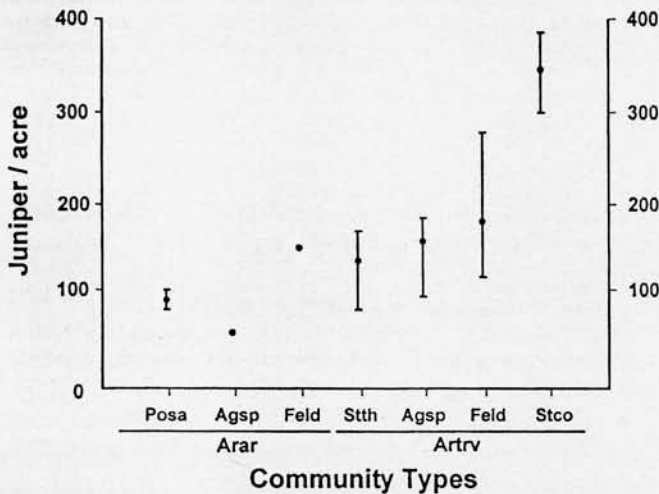


Figure 4—Percent juniper canopy cover for fully developed woodlands across different community types. Communities were designated as fully developed woodlands based on the criteria in table 1. Each point represents one 60 x 45 m plot. Vertical lines drawn through the points are anticipated ranges of maximum juniper canopy cover for each community type.

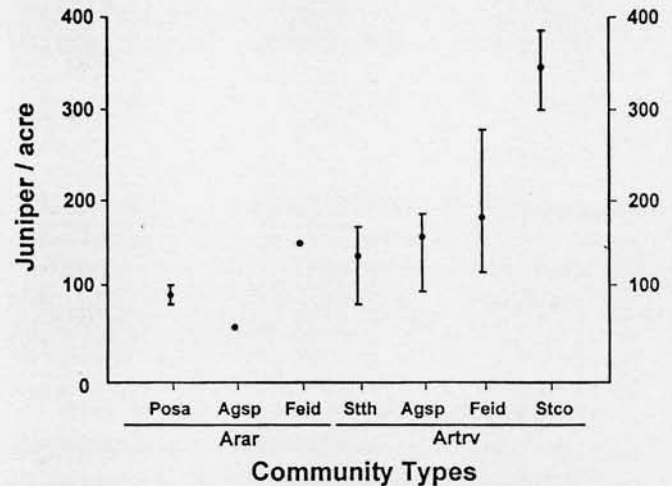


Figure 5—Density of mature juniper trees (near full height) for fully developed woodlands across different community types. Criteria in table 1 were used to determine stands that were fully developed woodlands. Points are means and lines represent range between maximum and minimum points occurring on plots within types.

changes in perennial grass abundance influenced by juniper woodland development across different sites. As mentioned previously, site variables appear to influence the impact of increasing juniper cover on perennial grass cover. Perennial grass cover was little affected by increasing juniper dominance on deep well-drained soils. This situation is most common on north aspects with deep clay loam to loamy Pachic Argixerolls and Pachic Haploxerolls characterized by mountain big sagebrush/Idaho fescue (*Festuca idahoensis*) and mountain big sagebrush/Columbia needlegrass community types. However, herbaceous cover was greatly reduced

in community types with restricted cemented ash layers. Herbaceous cover was reduced to 2 percent on a mountain big sagebrush/Thurber needlegrass (*Stipa thurberiana*) site growing on clay loam soils 14 to 16 inches deep, underlain by a thick, cemented silicic ash layer of rhyolite and rhyodacite composition (Bates et al. in press). Following release from tree competition, perennial herbaceous cover on this site increased 300 percent in the first two years. On other mountain big sagebrush/Thurber needlegrass community types, total herbaceous cover in closed woodlands was typically less than half compared to cover values in the early

stages of woodland development. In pinyon-juniper woodlands an inverse relationship between tree canopy cover and understory cover and biomass have been reported (Jameson 1967, Clary 1971, Clary and Jameson 1981, Tausch et al. 1981, Pieper 1990). For western juniper it appears this relationship is dependent upon certain site variables.

Conclusions

Western juniper occurs across a broad variety of soils and terrain creating a high degree of stand heterogeneity in structure, composition, function, and varying effects on ecological processes such as hydrology and nutrient cycling. Stand variability can also be attributed to varying stages of woodland development since western juniper expansion is relatively recent (within the last 120 years). As shrub steppe communities are converted to juniper woodlands community structure, composition, function, processes, and wildlife habitat suitability are altered. During conversion a threshold is crossed which moves communities to new steady states driven by different ecological processes. Once a threshold has been crossed it becomes significantly more difficult to return communities to previous states. The identification of spatial and temporal heterogeneity in western juniper woodlands is extremely important when evaluating potential resource problems, determining wildlife habitat values, developing management plans, and setting realistic goals and time frames.

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