Geographic Variation in Crown Structure and Foliage Biomass of Woodland Trees Across the Great Basin

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Abstract

The woodland portion of the Joint Sciences Program Funded SageSTEP (Sagebrush Treatment and Evaluation Project) has collected tree data from plots covering a range of tree dominance levels on 13 sites extending from southeastern Oregon southwest through California, Idaho and Nevada to western Utah. These data have been supplemented with compatible data from four additional Great Basin sites. Each tree species present on a site has a close relationship between its total crown area and its total foliage biomass across the plots for each site. The slopes of these relationships differ significantly across the Great Basin. For both juniper and pinyon species they are the lowest in Utah and generally increase to the north and west with the highest slopes for juniper in Oregon. These differences are shown to be the result of trees of a given crown diameter being the shortest in Utah and generally increasing in height to the north and west. Foliage biomass and one-hour fuels follow the same pattern with a four meter diameter juniper in Oregon having up to nearly twice the foliage biomass of a four meter diameter juniper in Utah. The reverse is true for tree height with a five meter tall juniper in Utah having up to three times the foliage biomass as a five meter tall western juniper in Oregon. These results have implications for differences in fuel loads, fire patterns, carbon sequestration and carbon cycling in woodlands across the Great Basin.

Introduction

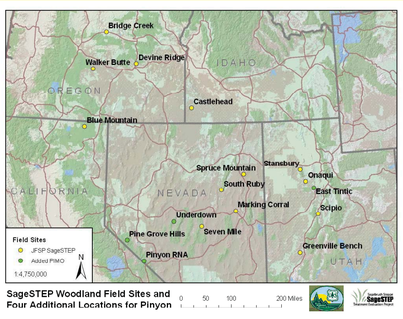
The "Sagebrush Steppe Treatment and Evaluation Project" (SageSTEP) has provided a Great Basin wide data set from 13 sites (Figure 1). Each site has 45 to 50 0.1 ha subplots covering the range of tree dominance. On each subplot the crown dimensions of all trees were measured. Four tree species were sampled: Colorado pinyon (*Pinus edulis*), single leaf pinyon (*Pinus monophylla*), Utah juniper (*Juniperus osteosperma*), and western juniper (*Juniperus occidentalis*). Data from four additional sites from other studies have been added for single leaf pinyon. These plots are the same size, and the trees were measured with the same techniques. These are the East Tintic Mountains with 14 plots (Tausch and McArthur, unpublished data), Underdown Canyon in the Shoshone Mountains, NV with 40 plots (Tausch and Chambers unpublished data), the Pine Grove Hills with 14 plots (Tausch unpublished data), and the Pinyon Reaearch Natural Area with 15 plots (Tausch unpublished data). These data were used to estimate differences in crown structure and foliage biomass distribution patterns between and within the tree species.

Methods

The foliage biomass of the individual trees was estimated for single leaf pinyon and Utah juniper using the methods and equations from Tausch (2009). The single leaf pinyon equations were also used with Colorado pinyon.

Western juniper foliage biomass estimates were based on the tree dimensions and biomass data collected by fuel load classes at Lakeview and Fort Rock sites in Oregon (Miller and Ratchford, unpublished data). Only the total one-hour biomass was physically collected in the field; foliage biomass was not separated. The methods in Tausch (2009) were used with the collected western juniper one-hour biomass data to provide the equations for determining the one-hour biomass for the individual western juniper trees. The ratio of foliage biomass to one-hour stem biomass from data collected for Utah juniper was used to estimate foliage biomass for the western juniper from its estimated total one-hour biomass.

Crown structure to foliage biomass relationships were compared across the region using linear regression analyses. The data for each sampled plot and tree species were then divided into crown diameter classes for further analysis and evaluation of the influence of crown structural differences on regression results between species and sites.



SageSTEP Woodland Field Sites and Four Additional Locations for Pinyon

Figure 1.

Results

When the western juniper one-hour biomass from its own equations is compared with western juniper one-hour biomass estimated using the equations from Utah juniper the results are essentially directly proportional (Figure 2). Because of this close relationship between equation results we used the ratio of one-hour stem biomass to foliage biomass in Utah juniper trees (Figure 3) to estimate the foliage biomass of western juniper trees from its estimated total one-hour biomass.

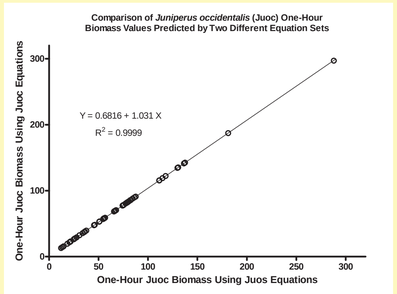


Figure 2.

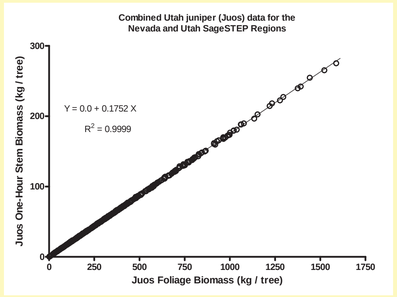


Figure 3.

At each site a significant linear relationship was found between the total cover (or total crown area) of each tree species and the total foliage biomass of the respective species (Figures 4 and 5). The slopes of these relationships varied between species, and depending on location in the Great Basin, within species. For example (Figure 6), all the slopes for Utah juniper in Utah are less than the slopes in Nevada, and most of these differences were significant (P≤ 0.05). All the slopes for western juniper in Idaho, California, and Oregon were significantly steeper (P ≤ 0.01) than for Utah juniper in either Nevada or Utah. Similar differences were present for pinyon but more regionally mixed (Figure 7). The two steepest slopes in Nevada were nearly twice as steep, and all the slopes in Nevada significantly steeper (P ≤ 0.05), than the shallowest slope in Utah. Based on the geographic and topographic differences between site locations with significantly different slopes they appear to be related to some aspect of growing season moisture stress. The higher the apparent moisture stress the shallower the slopes.

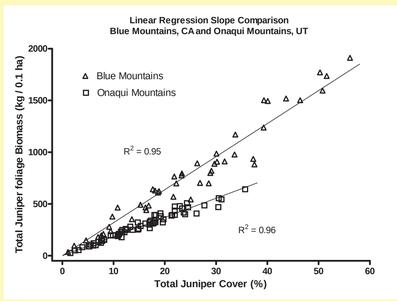


Figure 4.

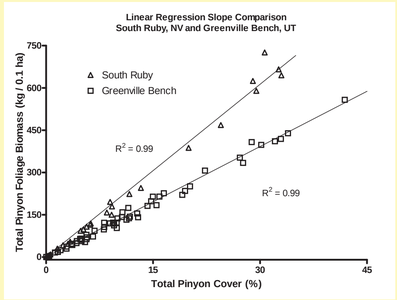


Figure 5.

Results (Cont.)

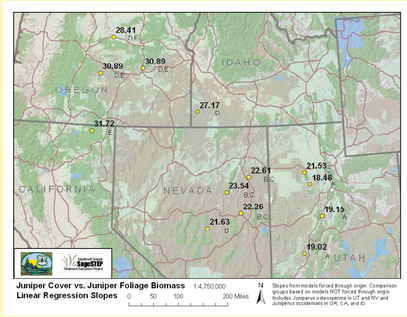


Figure 6. Slopes with different letters are significantly different (p < 0.05).

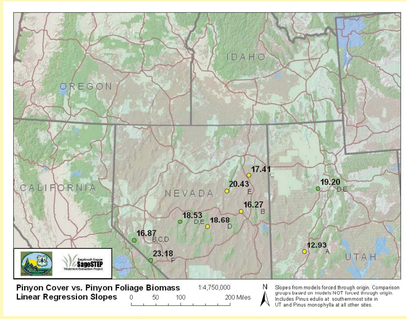


Figure 7. Slopes with different letters are significantly different (p < 0.05).

Because of the structure of the trees and the distribution of foliage biomass in their crowns (Tausch 2009), sites with steeper slopes should have more foliage biomass for the same crown area. To investigate this possibility, the trees in each subplot were divided into one-meter crown diameter classes. Comparing between tree species across all sites and subplots distinct differences are present (Figure 8). For all crown diameter classes greater than two, western juniper consistently has the highest average foliage biomass for each crown diameter class. Single leaf pinyon and Utah juniper are intermediate in foliage biomass by crown diameter class and essentially share the same relationship. Colorado pinyon has the least foliage biomass per crown diameter class. When Utah juniper and western juniper have the same crown diameter class, the western juniper can have up to nearly two times the foliage biomass of the Utah juniper.

Because of the crown structure and foliage biomass distribution patterns of these species (Tausch 2009), the differences in Figure 8 can only occur if the trees with the higher foliage biomass values for a crown diameter class, particularly within a species, are also taller (Figure 9). For all crown diameter classes western juniper is the tallest, single leaf pinyon is second, and Utah juniper and Colorado pinyon are tied for third. These same types of height differences are present within a species when comparing sites with significantly different slopes.

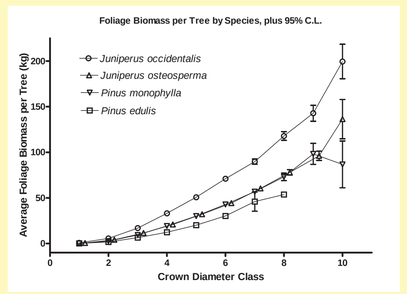


Figure 8.

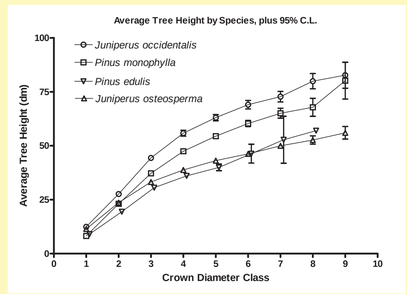


Figure 9.

Results (Cont.)

A comparison between average height and average foliage biomass across the crown diameter classes also showed interesting relationships (Figure 10). At some point all species show a slowing of their height growth in relationship to both crown diameter growth and increasing foliage biomass. This results in average foliage biomass increasing exponentially with increasing tree height for the larger trees. This happens with the lowest tree heights with Utah juniper, and Colorado pinyon has an intermediate relationship. This slowing of height growth occurs at a taller tree height for single leaf pinyon and western juniper than the others. For these species the relationships with foliage biomass are essentially identical. When Utah juniper and western juniper average the same height, the Utah juniper can average up to three times the foliage biomass of the western juniper. Even though single leaf pinyon grows in the same locations as Utah juniper, and thus experiences the same moisture stress levels as juniper, its height growth follows the same pattern as western juniper, which is found in locations with presumably lower moisture stress. It appears that single leaf pinyon is more tolerant of the growing season moisture stress that slows height growth than is Utah juniper. In the southwestern corner of the Great Basin where the least summer rainfall occurs, it is single leaf pinyon that is at the lowest elevations, not Utah juniper.

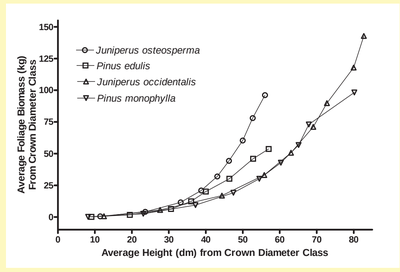


Figure 10.

TOTAL PLOT FOLIAGE BIOMASS COMPARISONS
Looking at total foliage biomass per subplot by crown diameter class distinct differences are again present between the tree species. (Figure 11). For plots that have only one of the tree species present Utah juniper foliage biomass peaks at crown class 4, Utah juniper at crown class 5 and western juniper at crown class 6. For all crown classed single leaf pinyon equals or exceeds the average foliage biomass of the two juniper species. The same is true for total plot foliage biomass.

The pattern changes when Utah juniper is mixed with one of the pinyon species (Figures 12 and 13). For both Nevada and Utah, juniper has more average foliage biomass in each crown class than either pinyon species. The difference is less, however, in Nevada than in Utah, particularly in the larger crown diameter classes. This may be related to an increased proportion of summer rainfall occurring in Utah than in Nevada. Foliage biomass peaks at the same crown diameter class as for Utah juniper when alone (Figure 11).

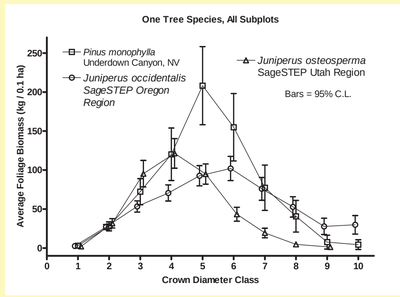


Figure 11.

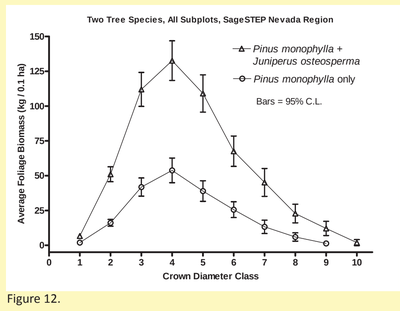


Figure 12.

Results (Cont.)

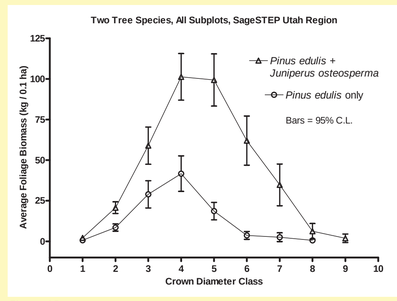


Figure 13.

Foliage biomass patterns in figures 11, 12 and 13 are the same for each individual species, and in a mix, even when separated by phase, or the level of tree dominance on the site. (Phase I = low tree dominance, Phase II = mid tree dominance, and Phase III = high tree dominance).

Differences are also present between the tree species in average total foliage biomass per plot when alone, or when in a two species mix (Table 1). Single leaf pinyon, when alone, has the highest total plot foliage biomass across all phases. This is followed by western juniper which averages 80% - 90% if the pinyon totals, also across all phases. Third is Utah juniper which average 50% - 66% of the pinyon totals (Table 1).

Average total foliage biomass per subplot in mixed (2) species sites in Nevada averages about 80% of that for Nevada pinyon when found alone (Table 1). For mixed species sites in Utah the totals are about 90% of that for Utah juniper when found alone. In Nevada mixed species stands, juniper is slightly less dominant, averaging about 2/3 of the total plot foliage biomass, than in Utah where it averages a little over 70% of the total.

Table 1. Average Total Foliage Biomass Per Subplot (kg / 0.10 ha) for each tree species by state in single species and mixed species stands. Numbers in parentheses represent percentages by phase between pinyon and juniper in mixed species stands.

State	Species	Phase I	Phase II	Phase III
Nevada	Pimo	292	602	1302
Oregon	Juoc	234	585	1087
Utah	Juos	197	367	640
Nevada	Pimo	41 (22%)	176 (36%)	396 (38%)
(mixed)	Juos	144 (78%)	318 (64%	652 (62%)
	Total	185	494	1048
Utah	Pied	43 (26%)	86 (25%)	187 (31%)
(mixed)	Juos	121 (74%)	264 (75%)	420 (69%)
	Total	164	350	607

Discussion and Conclusions

The four tree species found in the pinyon-juniper woodlands of the Great Basin are remarkably similar in their crown structural and foliage biomass distribution patterns. This is particularly evident in the pattern of the abundance of foliage biomass across the crown diameter classes. However, within a crown diameter class the magnitude of the foliage biomass can differ significantly between tree species, and even within a species between locations. These differences seem to be related to some aspect of sensitivity to growing season moisture stress that differs between species, and within a species between locations.

Prescribed fire in a Phase III pinyon-juniper woodland, Seven Mile SageSTEP burn plot.