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Estimating Foliage Yields on Utah Juniper from Measurements of Crown Diameter

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Highlight

This study indicates that tree foliage yield can be approximated from crown measurements. The relation between crown and foliage production is improved by including ratings of foliage denseness (sparse, medium, and dense) and soil characteristics. Such estimates are needed to fully evaluate site potential and condition of rangeland occupied by trees.

In order to fully evaluate site potential and condition of native rangeland, it is necessary to consider all vegetation including tree species such as juniper (*Juniperus osteosperma* (Torr.) Little). On areas occupied by juniper, estimating foliage yields of the trees is time consuming and requires constant training and checking to assure accurate estimates. This study, made in 1963 and 1964, indicates that reliable estimates of juniper foliage yield can be obtained from measurements of crown diameter. Such estimates can be made rapidly, and we believe that they can be made without personal bias.

Methods

All study areas were located in juniper stands in Utah at elevations between 5,000 and 7,000 ft, with average annual precipitation of 10 to 16 inches. Sixty-two areas were sampled: 33 were in Box Elder County in northwestern Utah; 16 in Beaver county in south central Utah; 5 in Carbon County; 3 in Sanpete County; 3 in Kane County; 1 in Tooele County; and 1 in Juab County. The study areas represent a wide range in soil texture and other soil characteristics.

At each study area, a 0.1-acre plot was selected on which tree dimensions and foliage and fruit yield were measured. Tree height and crown diameter were measured to the nearest 0.5 ft for each tree on each study area. Trees were classified into three groups (sparse, medium, dense) based on the compactness of the foliage (Fig. 1).

After the trees were measured and classified, foliage and fruit yield was carefully estimated. A "sample weight unit" with average foliage and fruit (a typical branch) was selected and used as a standard for estimating fruit and foliage yields. The number of weight units on each tree was counted. Foliage and fruit were then clipped from the "sample unit", air-dried and weighed. Total weight of foliage and fruit on each tree was computed by multiplying the numbers of weight units by the weight on the sample unit. Thirty percent of the dry weight of the foliage, plus one-half the dry weight of the fruit, was considered to be current growth.

The 30% figure was determined by observing the growth of twigs on branches which were sprayed with paint in the spring. Subsequent growth which was clearly evident varied greatly. Twig branchlets produced as little as one-sixteenth

FIG. 1. Examples of Foliage Denseness of Utah Juniper: Left, Sparse; Center, Medium; and Right, Dense.

inch of growth, whereas growth on terminal branches exceeded 10 inches.

Ratio of current growth to total foliage and fruit production varies from tree to tree, site to site, and from year to year. Some of the juniper leaves become dry and fall off during the second and third year after they form, and under drought conditions, some of the current year's growth is lost. Considerably more sampling and study are needed to evaluate current growth accurately. In this study, estimates of foliage production and regression curves are based on current foliage yield which was considered to be about 30% of the total green foliage. This agrees closely with the results found by Baskerville (1965) for balsam fir.

Fruit production on juniper normally requires two years; therefore, 0.5 the dry weight of fruit was considered to be current growth.

Soils

Soil scientists described soil profiles on each study area. The areas were then classified into range sites having similar soils, climate, topography, and exposure, based on their potential for producing similar kinds and amounts of native vegetation. The term "upland" here refers to the following climatic characteristics: cold snowy winters and hot dry summers with average annual precipitation 12 to 18 inches, but in a few instances as high as 20 inches on south and west exposures. It does not refer to elevational or topographic locations, although the juniper sites are all at elevations of 5,000 to 7,000 ft. The "semidesert" site has dry cold winters and dry hot summers with annual precipitation of 8 to 12 inches. Five range sites were sampled intensively enough to provide usable tree-site data. These are: upland loam, upland stony loam, upland gravelly loam, upland shallow loam, and upland shallow hardpan.

Following is a general description of soils on each of the sites:

Loam. — Soils are moderately deep to deep (28 inches to over 60 inches deep, but mostly 50 inches or more). Texture of the surface soils (0-10 in) varies from loams and gravelly loams to clay loam. The subsoil texture (10-40 in) varies from gravelly heavy loams and clays to very cobbly sandy clay loam, but are mostly clay loam and loam. The soils vary from mildly alkaline in the surface to strongly alkaline in the substratum (pH 7.4 to 8.8). Parent material is a loamy alluvium from mixed sedimentary and igneous rocks, primarily sandstones and limestones. They are mostly noncalcareous in the surface, but are strongly to very strongly calcareous in the substratum. Modally very small amounts of coarse fragments occur in the profile, but coarse fragments may be as high as 35% in some instances. The moisture-holding capacity averages 6 to 7 inches, but varies from 5 to 9 inches in a 6-ft profile.

Stony loam.—Soils are moderately deep to deep (22 to over 60 inches, but mostly over 60 inches). The surface (0-10 in) texture is gravelly or very gravelly loam to gravelly silty clay loam. The subsoil texture (10-40 in) varies from gravelly heavy loam to very cobbly sandy loam. The soils are mildly alkaline in the surface to strongly alkaline in the substratum (pH 7.6 to 8.8). Parent materials are mixed sedimentary and igneous but mostly basalt and limestone. They are mostly noncalcareous in the surface, but some are moderately calcareous. Lime content increased with depth to very strongly calcareous. Coarse fragments make up more than 50% of the profile as a whole. The moisture-holding capacity averages about 3.5 inches, but varies from 2.5 to 4.5 inches in a 6-ft profile.

Gravelly loam.—Soils are moderately deep (35 inches and slightly deeper). The surface texture is cobbly heavy loam to gravelly sandy loam. The subsoil texture is usually very cobbly loam, but on a few areas it is very gravelly coarse sand. The soils are moderately alkaline in the surface and strongly alkaline in the substratum (pH 8.0 to 9.0). Consequently, they are moderately calcareous in the surface and strongly calcareous in the substratum. Parent materials are lake sediments derived from limestone and sandstone. Coarse fragments make up 40 to 50% of the total profile by volume. Moisture-holding capacity is from 2.5 to 3.5 inches in approximately a 3-ft profile where most of juniper roots are found.

Shallow loam.—Soils are shallow (14 to 20 inches, but mostly around 15 inches over bedrock). The surface texture is cobbly heavy loam to very cobbly loam; the subsoil texture is very cobbly loam. Surface soils are moderately alkaline and calcareous, but the subsoils are strongly alkaline and calcareous. The pH is 8.3 and 8.8, respectively. The soil profile contains 35 to 75% coarse fragments by volume, but mostly less than 50%. Moisture-holding capacity varies from 2.0 to 2.5 inches in a 14 to 20-inch profile above bedrock where practically all of the roots are found.

Shallow hardpan. — Soils are shallow (14 to 20 inches but mostly 16 inches). Surface texture varies from cobbly loam to clay, but mostly silt loam. Subsoil texture is generally silty loam, but it varies from clay to loam. The soils are slightly acid to moderately alkaline in the surface and moderately alkaline in the substratum (pH 6.7 and 8.4). The surface may be noncalcareous to strongly calcareous and the substratum is very strongly calcareous. The soil profile is usually free of coarse frag-

Table 1. Proportion of Variation (r^2) accounted for by various regressions.

Upland Range Sites	No. Trees	Crown Class	Log Yield vs. Log Crown Diameter	Yield vs. Crown Diameter Squared	Log Yield vs. Log Height	Yield vs. Height Squared	Log Yield vs. Log Crown Diameter and Log Height	Yield vs. Height	Yield vs. Crown Diameter
Loam	314	Sparse	.85	.80	.61	—	—	.41	.67
	322	Medium	.93	.80	.73	—	—	.49	.74
	364	Dense	.92	.81	.80	—	—	.55	.74
	1000	All	.81	.66	—	—	—	.45	.59
Stony loam	35	Sparse	.64	.94	.53	.36	.64	.45	.90
	33	Medium	.95	.87	.84	—	—	—	—
	37	Dense	.92	.82	.78	—	—	—	—
	105	All	.77	.67	—	—	—	.57	.64
Gravelly loam	40	Sparse	.92	.93	.60	.36	.92	.41	.90
	21	Medium	.99	.98	.54	.42	.99	.41	.95
	33	Dense	.96	.96	.27	.31	.96	.29	.96
	94	All	.90	.86	.46	.23	.90	.25	.81
Shallow loam	36	Sparse	.76	.83	.55	—	—	.60	.76
	42	Medium	.96	.96	.55	—	—	.62	.91
	43	Dense	.95	.92	.72	—	—	.62	.92
	121	All	.77	.73	.60	.63	.78	.60	.72
Shallow hardpan	50	Sparse	.95	.92	.88	.57	.97	.49	.81
	45	Medium	.95	.95	.78	.66	.95	.59	.92
	46	Dense	.95	.93	.87	.70	.96	.53	.87
	141	All	.92	.87	.86	.61	.94	.46	.74

ments, but may have as much as 30%. Moisture-holding capacity varies from 1.5 to 3.0 inches in the 14 to 20-inch profile above the hardpan where practically all of the roots are found.

Table 2. Regression equations for all foliage classes for the various sites.

Site	Regression	Correlation Squared (r^2)
Upland gravelly loam	LY[1]=− .911+1.582 LCD[2]	0.90
Upland loam	LY =− .970+1.651 LCD	.81
Upland shallow loam	LY =− .938+1.604 LCD	.77
Upland stony loam	LY =− .848+1.519 LCD	.77
Upland gritty loam	LY =− .872+1.706 LCD	.91
Upland limy gravelly loam	LY =− .748+1.919 LCD	.90
Upland limy loam	LY =− .860+1.959 LCD	.78
Upland shallow hardpan	LY =− .895+2.012 LCD	.92
Upland shale	LY =− .983+1.965 LCD	.94
Semidesert stony loam[3]	LY =−1.242+1.947 LCD	.88
Upland clay	LY =−1.214+2.079 LCD	.93
Upland gritty stony loam	LY =−1.191+2.160 LCD	.97

[1] LY=Log of Yield
[2] LCD=Log of Crown Diameter
[3] Dense trees are exceptionally productive; sparse ones have very low production.

Results

Sample trees on most sites varied from 1 to 15 ft in height, and from 1 to 20 ft in crown diameter.

Equations were developed to relate weight of foliage and fruit to various tree measurements. Some of the relationships are logarithmic. The following relationships were tested:

- Log of yield with log of crown diameter
- Log of yield with log of height
- Log of yield with log of crown diameter and log of height
- Yield with height squared
- Yield with height
- Yield with crown diameter
- Yield with crown diameter squared
- Yield with crown surface
- Yield with crown volume

On most sites and foliage classes, a logarithmic equation suggested by other investigators (Kittredge, 1948; Cable, 1958; Rogerson, 1964) provided the best prediction equation. The precision varied with site and with the compactness of foliage on the various trees. In our study, foliage and fruit yield was more closely related to crown diameter and crown diameter squared than to tree height or crown volume (Table 1). The multiple regression using log of crown diameter and log of height was only slightly better than that obtained with log-of-crown diameter alone. The increased precision was not significant. The regressions for all foliage classes combined fall into three general groups (Table 2).

On the five sites which were sampled intensively enough to provide 30 or more trees in each

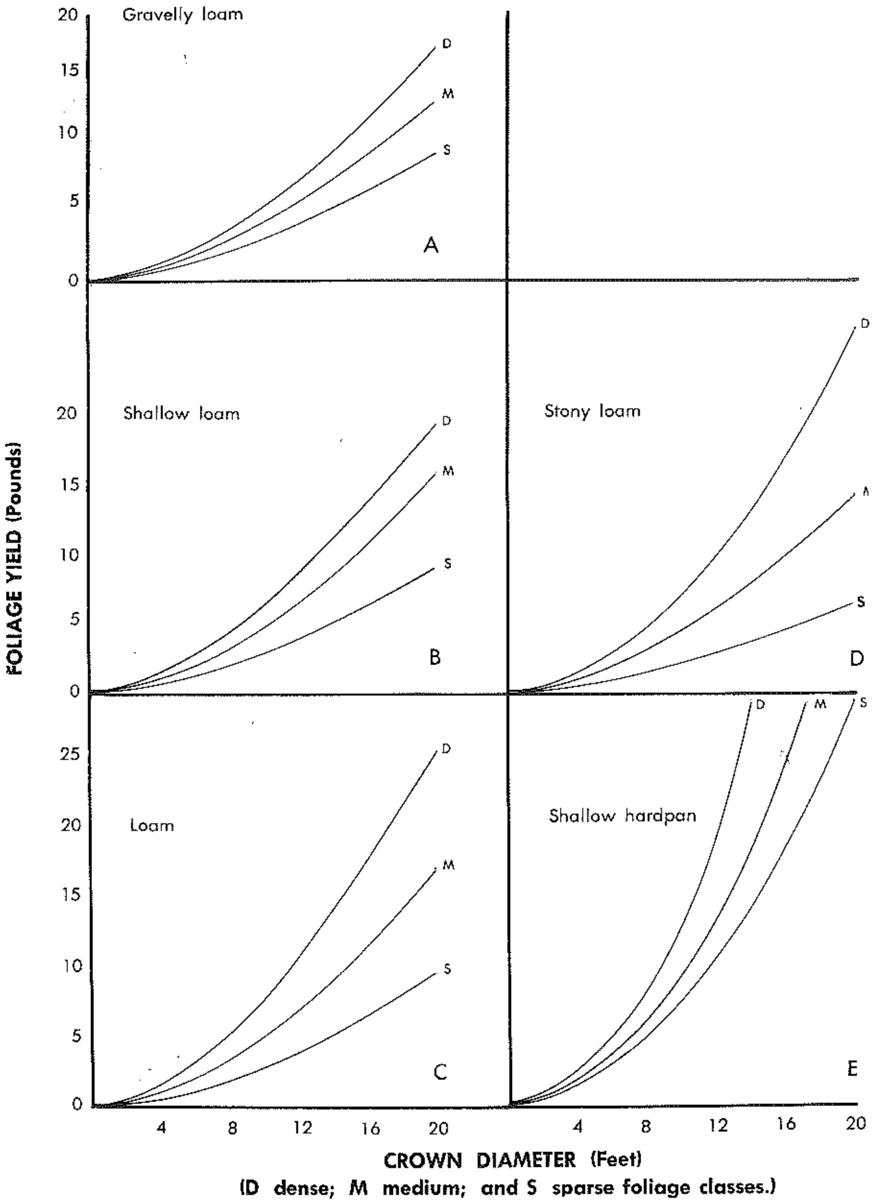

FIG. 2. Relation of current foliage yield of juniper to crown diameter for three foliage classes on five range sites.

of the three foliage classes, correlation and regressions were improved by considering the foliage classes separately. However, the three foliage classes vary widely from site to site (Fig. 2). Foliage yields per unit of crown are relatively similar for all foliage classes on upland gravelly loam and upland shallow loam (Fig. 2A and B). Yield of foliage per unit of crown for the medium and dense foliage classes was higher on upland loam sites and upland stony loam (Fig. 2C and D) where soil depth is unrestricted, than on the gravelly or shallow loam sites. On upland shallow hardpan (Fig. 2E) foliage yields per unit of crown diameter are much higher than on the stony, gritty, or gravelly loam sites.

Foliage yields on upland stony loam showed the widest variation of any range site. Foliage yields per unit of crown for the sparse foliage class were much lower than for any other site (Fig. 2D).

Yield estimates of juniper foliage and fruit are given in Table 3. This yield table can be used in the field to record foliage estimates for trees of any crown diameter within the three foliage classes.

Scatter diagrams show that foliage yields of most trees closely follow the regression curves. However, foliage yields of a few trees depart widely from the expected. More than half of these trees were heavy seed producers; the others appear to be exceptionally vigorous trees, with dense, thrifty foliage. Undoubtedly the yield estimates, based on the regression curves or yield tables, can be improved by treating the heavy seed-producing and the exceptional trees as a separate group. Yield tables could be used as a guide to assist the field examiners in judging foliage yield. Probably the yields of foliage and fruit (berries) should be determined separately.

The upland loam site was most intensively sampled and provides enough data (1,000 trees) for computing reliable regression equations for the three crown classes. The confidence limits for the mean yield of samples of 20 juniper trees for sparse, medium, and dense foliage classes are shown in Fig. 3. The gray dotted areas around the regressions indicate the 67% confidence limits for mean foliage weight and the outer solid lines are the 95% confidence bands.

Discussion

Higher yields of juniper foliage and fruit per unit of crown spread were obtained on upland shallow hardpan than on any other range site. This was surprising because the moisture-holding capacity of the soil mantle was only 1.5 to 2.5 inches. Soils on this site are shallow and have an impervious hardpan which holds most of the winter and spring moisture in the surface soils where it is readily available for rapid spring growth. Since the soils are shallow, adequate moisture is available for only a short period in the early spring and summer.

The site produced fewer trees per acre. Foliage was more compact, basal limbs and foliage extended closer to the ground, and roots were more abundant in the surface soil per unit of volume than on other sites.

The soil mantle on upland gravelly loam and upland shallow loam held 2.0 to 3.5 inches of moisture, but the soil mantle has either gravelly subsoil or fractured bedrock through which much of the winter moisture can escape. On these sites, juniper grows rapidly for only a short period in the spring. After surface soil moisture is depleted, the trees draw some moisture from gravelly subsoils or the cracks in the bedrock. During this latter period, growth is slow. Consequently, foliage is less dense per unit of crown spread than on the hardpan soils.

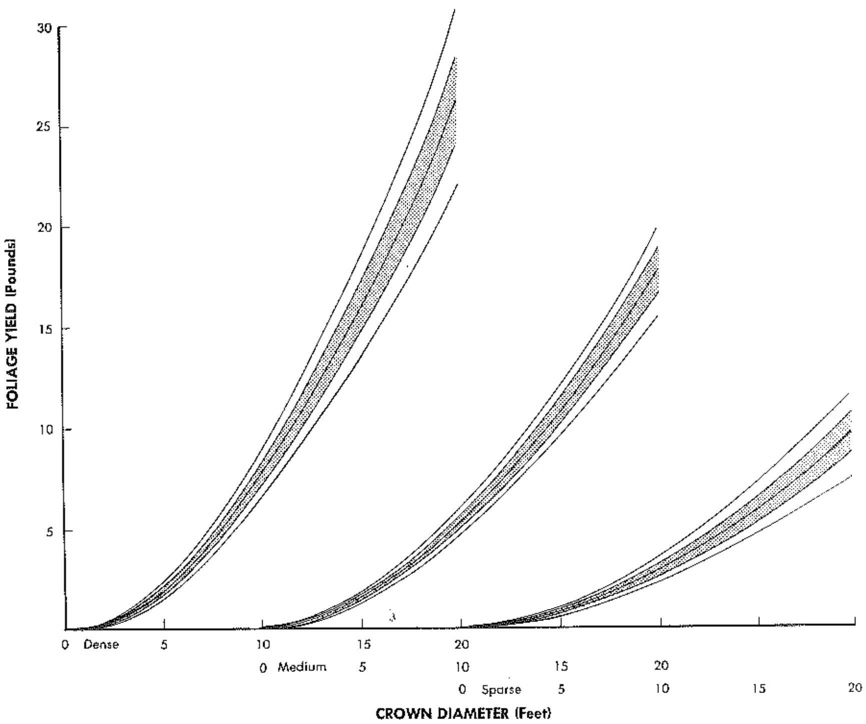

FIG. 3. Confidence limits (67 and 95%) for means of 20 juniper trees with sparse, medium and dense foliage on the upland loam site.

Table 3. Foliage and fruit current yields in pounds for juniper trees by crown diameter in feet on five sites and for three foliage classes.[1]

Crown Diam.	Upland Loam S	Upland Loam M	Upland Loam D	Upland Stony Loam S	Upland Stony Loam M	Upland Stony Loam D	Upland Gravelly Loam S	Upland Gravelly Loam M	Upland Gravelly Loam D	Upland Shallow Loam S	Upland Shallow Loam M	Upland Shallow Loam D	Upland Shallow Hardpan S	Upland Shallow Hardpan M	Upland Shallow Hardpan D
1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2
2	0.2	0.3	0.4	0.4	0.3	0.3	0.4	0.4	0.5	0.2	0.2	0.5	0.3	0.4	0.6
3	0.4	0.6	0.9	0.7	0.6	0.7	0.6	0.7	0.9	0.4	0.5	1.0	0.7	0.9	1.4
4	0.6	1.1	1.5	1.0	1.0	1.2	1.0	1.1	1.5	0.7	0.8	1.6	1.2	1.6	2.4
5	0.9	1.6	2.1	1.3	1.4	1.9	1.3	1.6	2.1	1.0	1.3	2.2	1.8	2.6	3.8
6	1.3	2.1	3.1	1.6	1.9	2.7	1.7	2.1	2.7	1.4	1.8	2.9	2.7	3.7	5.4
7	1.6	2.8	4.0	1.9	2.5	3.6	2.1	2.6	3.5	1.7	2.4	3.8	3.6	5.0	7.4
8	2.0	3.5	5.1	2.3	3.1	4.7	2.6	3.2	4.3	2.2	3.1	4.6	4.7	6.5	9.6
9	2.5	4.3	6.3	2.6	3.8	5.9	3.1	3.9	5.1	2.6	3.8	5.6	6.0	8.2	12.2
10	3.0	5.2	7.6	2.9	4.6	7.2	3.6	4.6	6.0	3.1	4.6	6.6	7.4	10.1	15.1
11	3.5	6.2	9.0	3.3	5.4	8.6	4.1	5.3	7.0	3.6	5.5	7.6	9.0	12.1	18.2
12	4.0	7.2	10.5	3.6	6.2	10.2	4.7	6.1	8.0	4.2	6.5	8.8	10.7	14.4	21.7
13	4.6	8.3	12.1	4.0	7.2	11.9	5.2	6.9	9.1	4.7	7.6	9.9	12.6	16.9	25.5
14	5.2	9.4	13.9	4.4	8.1	13.7	5.8	7.8	10.2	5.3	8.7	11.2	14.6	19.5	29.6
15	5.9	10.6	15.6	4.7	9.1	15.6	6.5	8.7	11.3	6.0	9.9	12.4	16.7	22.4	33.9
16	6.5	11.9	17.5	5.1	10.2	17.7	7.1	9.6	12.5	6.6	11.1	13.8	19.0	25.5	38.6
17	7.2	13.2	19.4	5.5	11.3	19.9	7.8	10.5	13.7	7.3	12.4	15.1	21.5	28.7	43.6
18	8.0	14.6	21.5	5.8	12.4	22.2	8.4	11.5	15.0	8.0	13.8	16.6	24.1	32.1	48.9
19	8.7	16.1	23.7	6.2	13.6	24.6	9.1	12.5	16.3	8.7	15.3	18.0	26.9	35.5	54.5
20	9.5	17.6	26.0	6.6	14.8	27.2	9.8	13.6	17.6	9.5	16.8	19.6	29.8	39.5	60.4

[1] S=Sparse; M=Medium; D=Dense.

The upland stony loam and upland loam sites have soils that are considerably different, particularly with respect to the coarse fragments; but the subsoils on both have a high clay content. Moisture-holding capacities on both sites are sufficient to store all the winter precipitation; however, juniper roots must penetrate deeper on the upland stony site to obtain the same amount of moisture because coarse fragments take up about half the soil volume. Growth of juniper extends over a longer period of time on these two sites than on the hardpan site, and this probably accounts for the open, less compact crowns.

The variations in foliage-production crown-diameter relations make it necessary to develop separate prediction estimates or yield tables for each site. However, once the yield tables are developed, they should be usable from year to year within the range site. Estimates of foliage yield computed from crown diameter should be considered as average annual yield rather than applying to a specific year, If yearly foliage yields or fluctuations in annual yields are to be considered, detailed studies or estimates of current growth will need to be made.

Summary

Reliable estimates of foliage and fruit yields of juniper can be made easily and quickly from measurements of crown diameter. The best correlations and regressions were obtained using logarithmic equations. Prediction equations were greatly improved by placing trees in crown classes (sparse, medium, and dense). With samples of 20 trees within each crown class, estimates of mean foliage and fruit can be predicted within 10% of the mean with 95% confidence on many sites.

Yield tables developed from preliminary sampling can be used by field personnel to record foliage and fruit yield for trees with various crown diameters as illustrated in Table 3.

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