Correlation Between Annual Rings of Woody Plants and Range Herbage Production[1]

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Highlight

Good correlations have been reported between precipitation and herbage production, and between precipitation and radial increment of growth rings in trees and shrubs. Because herbage production and ring growth are both affected by precipitation, the direct correlation between herbage production and tree-ring width was evaluated to determine the usefulness of tree rings for estimating herbage production. Significant positive correlation coefficients were obtained for 10 of 31 woody plant-herbage plant combinations from 11 locations in the western United States. It was concluded that the use of annual rings for estimating herbage yields is feasible, and that the technique warrants further investigation.

Correlations between precipitation and herbage yield have been frequently studied. The levels of correlation have varied from poor to excellent. Sneva and Hyder (1962) demonstrated good correlations between yield and precipitation in Oregon and other locations.

Where a high correlation exists between herbage yield and precipitation, it is possible to estimate herbage yield by a regression equation from precipitation data for those years where records are available. By comparing yields estimated from the regression equation with actual yields, the effects of a treatment can be evaluated independent of yield differences caused by fluctuations in yearly precipitation. Thus, herbage yields can be adjusted to a "normal year".

A. E. Douglass (1909), pioneered the use of tree-ring widths as indicators of climatic cycles and fluctuations, and started a vast amount of research in the field of dendrochronology (McGinnies, 1963). Schulman (1956) compiled extensive data on tree rings as they reflect variation in rainfall and streamflow throughout the west. Roughton (1962) has reviewed in detail much of the literature on dendrochronology with particular emphasis on applicability to game range. Ferguson (1964), in his detailed study of big sagebrush[2] in the southern portion of its distribution, found ring width more closely correlated to winter precipitation than summer precipitation. Speaking of a number of conifers, Fritts (1965) concluded "that there is a close relationship between widths of annual rings from trees on semiarid sites and variations in the aridity of the yearly climates."

Because good correlations between ring width and precipitation, and between herbage production and precipitation have been reported, the present study was undertaken to explore and evaluate the direct correlation between ring width and herbage yield. Such correlations, if high enough, offer many advantages over correlations with precipitation because of the long-time record offered by the tree rings and because precipitation records are frequently not available for the locations being studied.

Methods

Eleven locations were selected where (1) herbage yields were available for 6 or more years and (2) a woody species suitable for ring measurements was available in the immediate vicinity.

The woody plant samples were obtained from areas where they did not receive extra moisture from flooding, snowdrifts, or subsurface seepage. Whenever possible, the samples were chosen from the side or top of a hill adjacent to the area from which the herbage data were obtained. The individual shrubs and trees used for ring measurements were carefully selected to avoid individuals damaged by fire, porcupines, grazing or other disturbance.

The samples of woody species used for ring measurements were of two kinds: For big sagebrush and mesquite, cross-sections were cut from the lower stem. In the case of the tree species, cores were obtained with an increment borer, one core per tree. Both sample types were smoothed and polished on a belt sander with 400-grit belts. The annual rings were dated, and measured to the nearest 0.001 inch under a low-power microscope. Measurements were taken along two to four radii on each cross-section of sagebrush or mesquite. The number of woody plants sampled at each location is shown in Table 1.

Linear correlation coefficients (r) were computed for all of the ring width-herbage yield combinations. Significance of the correlation coefficients was then determined by a "t" test.

Results and Discussion

The coefficient for correlation values between the width of the annual rings and herbage production ranged from good to very poor (Table 1). Slightly less than half of the correlation co-

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[2] *Botanical names of species mentioned in text and tables are listed in Table 2.*

Table 1. Correlation coefficients for woody-plant annual-ring widths and forage species herbage yields.

Location	Woody Species	Number of woody plants sampled	Forage Species	Years of record	Coefficient of correlation
California					
Lassen Nat. For.	Ponderosa pine	6	Intermediate wheatgrass	12	.16
Colorado					
Fort Collins	Ponderosa pine	21	Crested wheatgrass	6	.63
	" "	21	Intermediate "	9	.22
	" "	21	Smooth brome	9	.28
	" "	21	Ranger alfalfa	10	−.08
Central Plains Exp. Range	Ponderosa pine	16	Mixed shortgrass	24	.71**
Idaho					
Hartman 1939	Juniper	10	Crested wheatgrass	9	.34
planting	"	10	Big sagebrush [a]	9	.36
	Big sagebrush	12	Crested wheatgrass	9	.76*
Hartman 1946	Juniper	10	" "	9	.23
planting	"	10	Fairway "	9	.21
	"	10	Russian wildrye	7	.40
	Big sagebrush	12	Crested wheatgrass	9	.65
	" "	12	Fairway "	9	.70*
	" "	12	Russian wildrye	9	.50
Oneida County	Juniper	12	Fairway wheatgrass	18	.56*
Montana					
Miles City	Big sagebrush	12	Blue grama	6	−.01
	" "	12	Western wheatgrass	6	.71
New Mexico					
Jornada Exp. Range					
South Well	Mesquite	3	Mixed perennial native grasses	9	.17
West Well	"	2	" " " "	9	.37
Oregon					
Squaw Butte	Juniper	10	Mixed native grasses	10	.88**
	"	10	Big bluegrass	8	.71*
	"	10	Bluebunch wheatgrass	8	.61
	"	10	Crested wheatgrass	8	.57
	"	10	Big sagebrush [a]	12	.34
	Big sagebrush	6	Mixed native grasses	10	.32
	" "	6	Big bluegrass	8	.78*
	" "	6	Bluebunch wheatgrass	8	.71*
	" "	6	Crested wheatgrass	8	.78*
Utah					
Benmore	Juniper	9	Crested wheatgrass	15	.72**
	"	9	Big sagebrush[a]	15	.38
	Big sagebrush	10	Crested wheatgrass	15	.29
Ephraim Canyon	Juniper	10	Crested wheatgrass	8	.27
N. of Ephraim	"	8	Crested wreatgrass	13	−.23

[a] Sagebrush ring widths rather than herbage production.
* = 5% level of significance; ** = 1% level of significance.

efficients are .50 or above, but only 10 are significant according to a "*t*" test. For several locations the data were plotted; no evidence of non-linear relationships were found. The correlation coefficients appear to have been influenced by a number of factors.

The number of usable samples of the woody species was sometimes less than desired. Frequently, variation between individual woody plants was considerable; by using more samples, it was sometimes possible to reduce the effect of these variations. Where the annual rings indicated disturbance (for example, a sudden increase in ring width that results from removal of a neighboring tree), that individual plant was removed from the sample. For some trees it was not possible to be sure of the dating of the rings; these indviduals were also discarded. Elimination of these questionable individual woody plants reduced variability.

No doubt there are cases where either the woody plant or the forage plants were influenced by unknown or unrecognized factors. For example, it has been suspected that the intermediate

Table 2. Common and botanical names of species mentioned in text and tables.

Common name	Botanical name
Alfalfa	*Medicago sativa* L.
Bluegrass, big	*Poa ampla* Merr.
Brome, smooth	*Bromus inermis* Leyss.
Ephedra	*Ephedra spp.* L.
Grama, blue	*Bouteloua gracilis* (HBK.) Lag. ex Steud.
Juniper	*Juniperus sp.*
Mesquite	*Prosopis juliflora* (Swartz) DC.
Pine, ponderosa	*Pinus ponderosa* Dougl. ex Laws.
Sagebrush, big	*Artemisia tridentata* Nutt.
Saltbush, fourwinged	*Atriplex canescens* (Pursh) Nutt.
Wheatgrass, bluebunch	*Agropyron spicatum (Pursh)* Scribn. and Smith
Wheatgrass, crested	*Agropyron desertorum* (Fisch. ex Link) Schult.
Wheatgrass, fairway	*Agropyron cristatum* (L.) Gaertn.
Wheatgrass, intermediate	*Agropyron intermedium* (Host) Beauv.
Wheatgrass, western	*Agropyron smithii* Rydb.
Wildrye, Russian	*Elymus junceus* Fisch.

wheatgrass, smooth brome, and alfalfa at Fort Collins receive some additional water from a water table of variable depth. The junipers sampled at Hartman may have been near enough to a gully to have been influenced by occasional flooding.

A woody species sometimes showed a good correlation with a forage species at one location, while at another location, the correlation with the same forage species was poor. For example, in the 1939 planting at Hartman, the correlation between big sagebrush and crested wheatgrass was good and the correlation between juniper and crested wheatgrass was poor; the opposite was observed at Benmore where juniper had a good correlation with crested wheatgrass production while sagebrush was poorly correlated.

Correlations between ring widths of juniper and big sagebrush were poor at three locations where both species occurred. At Squaw Butte both woody species correlated well with production of big bluegrass. However, yields from the mixed native grass pasture were significantly correlated only with juniper, but correlation coefficients for bluebunch wheatgrass and crested wheatgrass were significant only for big sagebrush. Thus, two woody plants that respond differently to climatic fluctuations showed good correlations to one forage species. At the same time, these two woody species had widely divergent correlations with other forage species.

At Central Plains Experimental Range, no suitable woody species were available. Increment cores were obtained from ponderosa pine trees growing in the mountains about 40 miles to the west. The highly significant correlation coefficient of .71 demonstrates that it was not always necessary to obtain the woody plant samples from the immediate vicinity of the herbage samples. Perhaps one reason for this good relationship is that a region as a whole tends to be wet or dry in a given year, and the trees and forage are growing in the same climatic region.

While "ring width represents an integration of the favorableness of the environment of approximately a year's duration" (Fritts, 1965), one must recognize that precipitation and temperature have relatively more influence during specific seasons. Thus, Fritts et al. (1965) report that at Mesa Verde, Colorado, the "climate conditions which produce narrow rings in juniper are a dry, hot autumn; a dry, cool winter; and a dry, warm spring." Fritts (1965) also reported that "An average picture . . . indicates that low moisture and high temperature during December through May is most significantly related to narrow rings in ponderosa pine." The reported close relation between winter precipitation and width of annual rings in big sagebrush (Ferguson, 1964) probably accounts for the high correlation of big sagebrush with western wheatgrass and the low correlation with blue grama at Miles City. Western wheatgrass, a "cool-season" species, and big sagebrush were no doubt affected more by winter and spring precipitation than was blue grama, which normally responds strongly to summer rainfall.

Some woody plants (including fourwinged saltbush and ephedra) were unusable because annual rings could not be clearly defined. With other species (such as mesquite), the rings are difficult to discern and measure accurately. Still other species are subject to false rings, missing rings, or erratic ring growth. Juniper has been subject to considerable suspicion as to its usefulness in indicating climatic fluctuations. This study indicates that, at least in some cases, it can be a moderately reliable indicator of herbage yields.

Before herbage yields can be estimated, it is necessary to compute a regression formula for a specific woody plant-forage plant combination for each location. There is no standardized technique for obtaining annual-ring widths, so a regression formula will apply only to the set of annual-ring measurements from which the formula was derived. For this reason, no regression formulas are presented here.

Because of less consistent relations, attempts to obtain a "common herbage response" regression similar to that of Sneva and Hyder (1962) were unsuccessful.

Conclusions

The relatively high correlation coefficients obtained from some locations indicate that the use of annual rings to estimate herbage production can be a useful technique. However, considerably more experience is needed with this type of estimation. The occurrence of a number of low correlations shown in Table 1 is probably not as serious as it might appear; many correlations between precipitation and yield are just as low, but these low correlations seldom appear in print. It is hoped that other workers having access to more extensive yield data will be able to make additional correlations. Along with these, an evaluation of the sensitivity of the various woody species to rainfall or herbage production should be explored further; some species, such as the mesquite in this study seem relatively insensitive to climatic fluctuations (called a "complacent" species by the dendrochronologist in contrast to "sensitive" species). The applicability of this technique to any particular area will need to be determined for that area and for the specific forage plants and woody plants involved.

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