Herbage Production Following Tree and Shrub Removal in the Pinyon-Juniper Type of Arizona

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Abstract

Herbage production was evaluated after overstory removal from different sites within the pinyon-juniper type. Average annual production varied from 43 to 643 kg/ha before treatment and 715 to 3,703 kg/ha after treatment. Production variation among sites was related to annual precipitation, pretreatment tree canopy, pretreatment nitrate-nitrogen, and presence or absence of limestone soils. Grasses increased in the composition from 46 to 73% on the average, while forbs decreased from 21 to 19%, and half-shrubs and shrubs decreased from 33 to 8%.

The pinyon-juniper vegetation type covers a substantial portion of western and southwestern United States. Recent estimates range from 17.3 million (Forest-Range Task Force 1972) to 32.5 million ha (West et al. 1975), with 3.4 million (Forest-Range Task Force 1972) to 5.7 million ha (Ffolliott and Thorud 1975) in Arizona. The extent of this vegetation type makes it important even though the per-hectare productivity is relatively low.

The diversity of products available from pinyon-juniper woodlands, which gives it some of its appeal, has also resulted in conflicts of use (Gifford and Busby 1975; Aldon and Loring 1977). Many have suggested that the best use is as range for grazing animals (Springfield 1976). As a result, substantial areas of pinyon and juniper trees have been removed to reduce forage plant competition.

Better productivity information is needed so research and management attention can be focused to obtain the best yield of all products and amenities from this vegetation type. The objective of this study was to determine the herbage production after overstory removal from various sites within the pinyon-juniper type of Arizona. Sites with soils developed from different parent rocks were evaluated for their ability to produce native herbaceous vegetation.

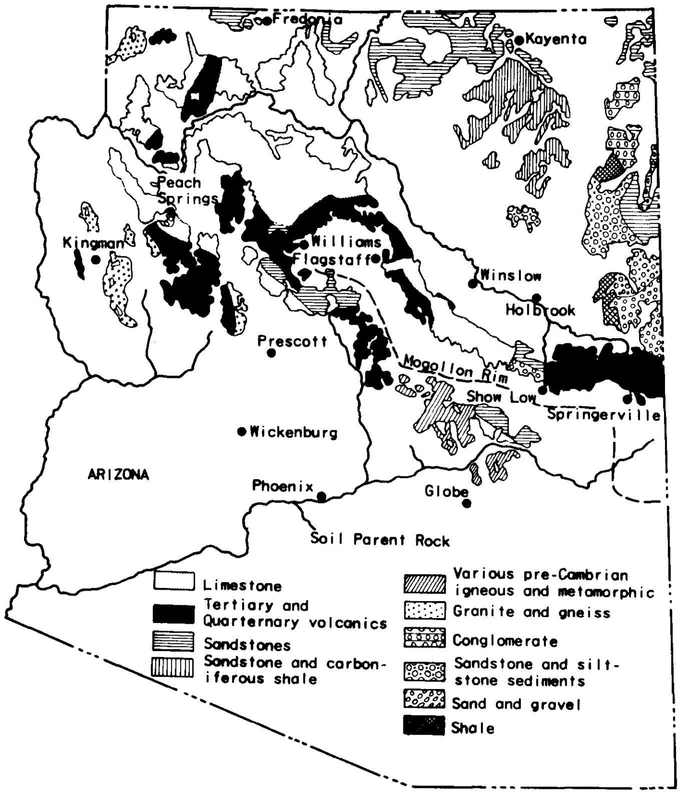

Fig. 1. *Simplified geologic map of the pinyon-juniper type in Arizona.*

Description

Climate

The climate throughout the pinyon-juniper type is rather severe for tree growth, characterized by low precipitation, low relative humidity, hot summers, and much clear weather and intense sunshine. Average annual rainfall in the Arizona pinyon-juniper type varies from 30 to 50 cm while typical January and July mean temperatures are 2° and 22° C, respectively.

In Arizona, a prominent and unique climatic feature is the presence of two distinct precipitation periods. This biomodal pattern is most distinct in the Flagstaff/Prescott area (Jameson 1969). Precipitation generally comes from the Pacific Ocean during the winter and from the Gulf of Mexico during the summer. Topography and typical storm paths combine to produce variations in precipitation. Central Arizona receives the most precipitation since it experiences the full effect of both summer and winter storms, whereas northern and western Arizona is summer dry, and east-central Arizona is winter dry.

Soils

The parent rocks of soils supporting pinyon-juniper vary widely from basalt, limestone, sandstone, and granite to mixed alluvium (Fig. 1). Soil surface textures vary from stony, cobbly, and gravelly sandy loams to clay and clay loam. About one-third of Arizona pinyon-juniper grows on soils formed from basalt. Most of this is in the Springerville and Thunderbird soil series (Jameson and Dodd 1969). The next largest area is underlain by Kaibab and Redwall limestones. The sandstones are also a major group of parent rocks.

Information developed by the U.S. Dept. Agr. Soil Conservation Service[1] suggests that herbage production is expected to be

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[1]Soil Conservation Service. Technical range site descriptions. Phoenix, Arizona. Memo.

less on limestone than on basalt soils, especially on shallow soils.

Vegetation

The pinyon-juniper type constitutes the largest "forest" type in Arizona (Shupe 1965). This type is commonly referred to as a woodland rather than a forest because the trees are generally too small for sawtimber. Although the physiognomy appears rather monotonous, consisting of a rather open forest of low, round-crowned trees, there are variations of both tree overstory and the predominant understory species. The most consistent tree species is pinyon *(Pinus edulis);* however, one or several juniper species usually dominate the stand. Typical juniper-understory combinations are one-seed juniper *(Juniperus monosperma)* with blue grama *(Bouteloua gracilis)* in the dry winter areas north of the Mogollon Rim; Utah juniper *(J. osteosperma)* with big sagebrush *(Artemisia tridentata)* in the areas with cold, moist winters in the most northerly portion of the State; and alligator juniper *(J. deppeana)* at higher elevations and Utah juniper at lower elevations, with chaparral [mainly shrubby oaks (*Quercus* spp.) and manzanita (*Arctostaphylos* spp.)] south of the Mogollon Rim where winters are cool and moist.

Study Areas

This study was conducted on a 22 0.4-ha plots distributed from northwest of Peach Springs in western Arizona to Show Low in the east-central portion of the State. The plots were located in pairs—one on each side of a tertiary or quaternary basalt flow boundary. This provided an opportunity to compare herbage production across the State on soils developed from basalt flows versus soils developed from nonbasaltic geologic formations (Table 1).

Criteria used to select the locations were:

1. Soils appeared to be typical for the geologic formation.
2. Slopes were less than 10%.
3. Plot pairs were within a single range unit (had a similar grazing history).
4. The two members of the pair were within 0.8 km of each other.

Methods

Treatment

The overstory of pinyon-juniper trees was killed mostly by girdling, although sawing was necessary in some cases. The dead trees remained on the plots, thus soil disturbance was minimal. Stumps of alligator juniper were sprayed with polychlorobenzoic acid[2] in diesel oil to prevent sprouting (Jameson and Johnsen 1964). Shrub live oak *(Quercus turbinella)* was treated with fenuron in 25% pellets. Other shrubs were treated with polychlorobenzoic acid. Herbaceous forbs and half-shrubs on all plots were treated with 2,4-D butoxy ethanol ester (Johnsen 1962). Followup spot treatments of a similar nature were made for two years. The plots were fenced to exclude livestock, but not wildlife, following the initial treatments.

Measurements

Within each 0.4-ha plot, 50 subplots were randomly located. These were the basis for most study measurements. Tree and shrub overstory canopy was determined before treatment with a spherical densiometer (Lemmon 1956). Rock, litter, and herbaceous basal cover were measured with a point frame using 50 points spaced 1 × 2 dm within a 1 × 1 m frame.

Standing crop measurements of vegetation (considered to be a measure of annual herbage production for all understory plants except perennial succulents) were made every other year near the end of the growing season. Green weight estimates were made by trained observers on 50 0.9-m^2 subplots per plot. One of every five plots was chosen at random to be clipped and oven-dried to provide a ratio conversion for herbage data to a dry-weight basis.

Complete soil profile descriptions[3] were made according to standard soil survey techniques on each plot (Soil Survey Staff

[2]This paper reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that uses discussed here have been registered. All use of pesticides must be registered by appropriate state and federal agencies before they can be recommended.

[3]Soil profile descriptions were made by G. Wendt and M.L. Miller, U.S. Dep. Agr. Soil Conservation Service, and T. Anderson and W.R. Mitchell, U.S. Dep. Agr. Forest Service. Revision of nomenclature by D.R. Taylor, U.S. Dep. Agr. Soil Conservation Service.

Table 1. Plot locations and selected characteristics.

Location name	County	Parent rock	Soil series	Annual precipitation (cm)	Tree canopy cover (%)	Nitrate-nitrogen (kg/ha)
Babbitt Lake	Coconino	Kaibab limestone	Tortugas gravelly loam	31.8	31	9
		Basalt	Thunderbird stony loam	31.8	29	1
Double A	Coconino	Mixed alluvium	Disterheff gravelly loam	46.0	22	1
		Basalt	Springerville cobbly clay	46.0	23	3
Black Canyon	Mohave	Redwall limestone	Tortugas stony and rocky loam	39.1	12	1
		Basalt, cinders, and ash	Springerville stony silty clay	39.1	17	13
Yampai	Yavapai	Supai sandstone	Dye loam	37.1	10	3
		Basalt	Springerville stony clay	37.1	9	9
Indian Mountain	Yavapai	Granite alluvium	Lynx gravelly loam	44.2	18	31
		Basalt and cinders	Springerville very stony clay	44.2	19	1
Hell Canyon	Yavapai	Redwall limestone	Winona stony gravelly loam	34.5	5	1
		Basalt	Thunderbird stony silty clay	34.5	0	9
Witty Tom	Yavapai	Quartzite alluvium	Cross stony, silty, clay loam	39.1	9	9
		Basalt	Springerville stony clay	39.1	19	1
Rimrock	Yavapai	Verde Lake limestone	Retriever loam	31.8	13	1
		Basalt and cinders	Thunderbird stony clay loam	31.8	2	22
Sand Rock Draw	Yavapai	Kaibab limestone	Hogg loam	56.6	29	1
		Basalt	Thunderbird cobbly clay loam	56.6	7	1
Buckhead Mesa	Gila	Mazatzal quartzite	Daze cobbly sandy loam	56.4	43	1
		Basalt	Springerville very stony clay	56.4	23	1
Lone Pine	Navajo	Tertiary outwash	Showlow gravelly loam	37.1	13	3
		Basalt	Thunderbird clay	37.1	16	1

Table 2. Post-treatment herbage production (kg/ha).

Location	Parent rock			
	Basalt		Nonbasalt	
	Average	Range	Average	Range
Babbitt Lake	1551	1213–1834	971	858–1096
Double A	1426	827–2094	979	771–1221
Black Canyon	1503	1088–2207	1184	796–1546
Yampai	1077	839–1318	1148	1020–1316
Indian Mountain	1165	692–2083	3224	1220–4651
Hell Canyon	1090	643–1443	840	703–1003
Witty Tom	1804	1100–2378	1770	1096–2109
Rim Rock	715	692–735	869	536–1091
Sand Rock Draw	1731	1273–2595	1371	1150–1551
Buckhead Mesa	1809	1488–2207	3703	3352–4221
Lone Pine	993	638–1455	771	559–1020
Average	1351		1530	

1951). Soil samples were collected from each horizon, and mechanical analyses were made in the laboratory by the Bouyoucos hydrometer method.

Soil samples were collected from the surface 25 cm of each soil profile and analyzed for nutrient content with LaMotte[4] soil test kits.

A precipitation storage gage was established at each plot pair, and readings were taken at least twice yearly. Gages were charged with oil and ethylene glycol in the winter and oil only in the summer. The average season distribution of precipitation at each study site was estimated based upon records of nearby U.S. National Weather Service Stations (Sellers and Hill 1974). Selection of comparison stations was made on the basis of proximity and similarity to the study areas in elevation, physiography, vegetation, and average annual precipitation—in most cases two adjacent stations were used.

Analysis

The analysis of herbage production (grasses, forbs, and shrubby plants) was based on an average of the fourth, sixth, and eighth post-treatment years in order to avoid the initial disturbance of treatment. The data were subjected to multiple regression analysis to determine if certain site characteristics could be used to estimate post-treatment herbage production. Several initial regression screenings were conducted to investigate correlations of herbage production with various topographic, climatic, soil, and plant characteristics of the site. Comparison among soils groups were made using *t*-tests.

Results and Discussion

Herbage Production

Average herbage production after overstory removal varied from 715 to 3,703 kg/ha with the highest production occurring on a quartzite and on a granite soil (Table 2). The production before treatment ranged from 43 to 643 kg/ha. Production values compared across all sites showed no significant difference between basalt and nonbasalt means.

The variables most effective for prediction of post-treatment production were annual precipitation, antecedent or pretreatment tree canopy cover, antecedent or pretreatment nitrate-nitrogen, and presence or absence of limestone soils. The effects of these variables were consistent when combined with the different variables tested, and there were logical cause-effect reasons for their use.

Average annual precipitation was used as a predictor since differences in seasonal distribution had no detectable effect on herbage production. Pretreatment tree canopy cover apparently was an effective predictor because, under stable conditions, those sites which support the most tree cover are usually the most productive (Lanner 1975; Springfield 1976). Pretreatment nitrate-nitrogen appears to be a useful indicator of site fertility, particularly on those sites with little tree canopy cover. Climax plant communities seem to inhibit nitrification (Rice and Pancholy 1972, 1973; Lodhi 1978) and there is evidence of such effect in the pinyon-juniper woodland (O'Rourke and Ogden 1969). Apparently, the amount of nitrate tends to be low in the presence of a tree cover, but varies in the absence of tree cover reflecting productivity of the site. Thus, the amount of nitrate-nitrogen present helps differentiate among those which have a low tree canopy cover because of low productivity and those which have a low tree canopy cover because of historical events such a disturbance by cutting or fire.

Tree canopy cover did not appear to be an effective predictor of herbage production on limestone soils. Reduced herbage production on limestone-derived soils in comparison to most other soils in this study is evidently a reflection of a worldwide phenomenon (Whittaker and Niering 1968); therefore, a joint variable (tree canopy cover × presence or absence of limestone soils) was included in the analysis.

The equation recommended for estimating post-treatment herbage yield is:

$$Y = 42.1\ X_1 + 45.2\ X_2 + 46.4\ X_3 - 32.7\ X_4 - 1174 \quad (1)$$

where: Y = average annual herbage production in kg/ha
X_1 = average annual precipitation in cm
X_2 = pretreatment canopy cover in percent
X_3 = pretreatment nitrate-N in kg/ha
X_4 = canopy cover x presence (1) or absence (0) of limestone soil

$R^2 = 0.77$
$S_{s.x} = 429$

Of the above variables, nitrate-N data are probably most apt to be lacking for any particular area. The following equation can be used if no nitrate-N data are available:

$$Y = 33.0\ X_1 + 38.8\ X_2 - 33.5\ X_4 - 405 \quad (2)$$

$R^2 = 0.58$
$S_{y.x} = 556$

These equations were developed from a data set with the following ranges in independent variables: precipitation 31.8 – 56.6 cm; nitrate-N 1 – 31 kg/ha; and canopy cover 0 – 43 %.

Production levels measured in this study exceeded those generally reported under grazed conditions (Arnold et al. 1964; Aro 1971; Clary 1971) although some reports include only those plants deemed as "forage." Reduced herbage production on grazed range compared to ungrazed range is common in the West (Pase and Thilenius 1968; Reynolds and Martin 1968; Smith 1967). Therefore, caution should be used in projecting the actual levels of production obtained in fenced plots to that expected under grazed conditions.

Botanical Composition

The proportion of grasses by weight in the post-treatment com-

[4]Mention of trade name does not constitute endorsement by the U.S. Department of Agriculture.

Table 3. Average annual production for grasses, forbs, half-shrubs, and shrubs; and live biomass for perennial succulents.

	Annual production (kg/ha)	
	Pre-treatment[1]	Post-treatment[1]
Grasses		
Three-awn (*Aristida* spp.)	1	35
Side-oats grama (*Bouteloua curtipendula*)	5	155
Black grama (*B. eriopoda*)	2	22
Blue grama (*B. gracilis*)	31	350
Hairy grama (*B. hirsuta*)	6	69
Tobosa (*Hilaria mutica*)	30	62
Bullgrass (*Muhlenbergia emersleyi*)	T[2]	69
Ricegrass (*Oryzopsis hymenoides* and *O. micrantha*	1	18
Vine-mesquite (*Panicum obtusum*)	1	31
Bluegrass (*Poa fendleriana* and *P. longiligula*)	1	28
Bottlebrush squirreltail (*Sitanion hystrix*)	1	84
Sand dropseed (*Sporobolus cryptandrus*)	1	31
Others	20	97
Total	100±17	1051±139
Forbs		
Eriogonum (*Eriogonum* spp.)	3	1
Spurge (*Euphorbia* spp.)	T	21
Common sunflower (*Helianthus annuus*)	T	16
Toadflax penstemon (*Penstemon linarioides*)	2	1
Russian thistle (*Salsola kali*)	T	41
Flannel mullein (*Verbascum thapsus*)	0	40
Annual goldeneye (*Viguiera annua*)	T	42
Others	41	113
Total	46±10	275±51
Half-shrubs and shrubs		
Rubber rabbitbrush (*Chrysothamnus nauseosus*)	2	T
Wright eriogonum (*Eriogonum wrightii*)	1	16
Broom snakeweed (*Gutierrezia sarothrae*)	54	89
Mimosa (*Mimosa* spp.)	7	0
Others	6	9
Total	70±20	114±27
Grand Total	216±30	1440±158
	Biomass (kg/ha)	
Perennial succulents		
Utah agave (*Agave utahensis*)	130	0
Prickly-pear (*Opuntia* spp.)	242	0
Blue yucca (*Yucca baccata*)	5	0
Others	1	0
Total	378±194	0±0

[1]Pretreatment data–1 year
Post-treatment data–3 years
[2]T = less than 1/2% of production

position increased significantly to 73% from a pretreatment average of 46% (excluding perennial succulents) (Table 3). The most prominent species was blue grama with about 24% of the post-treatment production. Interestingly, blue grama, which has a reputation of low productivity and had not been expected to respond greatly to pinyon-juniper removal (Jameson 1970), increased approximately 11 times, while tobosa, a seemingly more vigorous species, only doubled.

The proportion of forbs decreased slightly from 21 to 19%, but the tall annual forbs were much more evident after treatment. Half-shrubs and shrubs dropped significantly from 33 to 8% of the composition even though the most abundant nongrass species after treatment was broom snakeweed.

The substantial live biomass of perennial succulents was eliminated by the herbicides (Table 3).

The treatment applied (removal of trees, application of herbicides, and protection from livestock grazing) was designed to allow maximum increase of native grass species. The treatment was successful in increasing both the quantity of grasses produced and, generally, the proportion of grasses in the composition. However, the post-treatment proportion of grasses, although averaging 73%, ranged from 40 to 92%. This proportion was not predictable from current site information. For example, the post-treatment proportion of grasses was not related to the site characteristics used to predict herbage production, nor was it related to soil parent rock or pretreatment composition. General observation suggests that a part of the differences in composition response may result from particular species-soils interactions, but further research is needed to determine this. The only difference in composition among plots which appeared to be consistent was a lesser proportion of shrubby plants on limestone soils (significant at 0.05 level).

Conclusions

Considerable variation exists in herbage production potential of the pinyon-juniper woodland. Therefore, if the intent is to manage portions of the woodland for maximum herbage yield, careful consideration should be given to site selection to obtain the best return for input of labor and energy (Clary et al. 1974). The highest herbage yields in this study were obtained from sites with high annual precipitation, high pretreatment tree canopy or nitrate values, and nonlimestone soils. In Arizona, these conditions are most common just south of the Mogollon Rim. Since costs of converting from pinyon-juniper to grass increase with tree canopy coverage (Jameson 1971), cost efficiency may suggest treatment of sites with high nitrogen values ahead of sites with high tree canopy percent.

Average production after tree removal, herbicide application, and protection from grazing increased from the pretreatment values by the following proportions: grasses, 10-1/2 times; forbs, 6 times; shrubby plants, 1-2/3 times; and total herbage, 6-2/3 times.

Suggested further investigations include (1) the apparently high productivity of granite and quartzite soils, and (2) the seemingly slow response of tobosa after overstory removal.

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