Figure 1. This illustration demonstrates how ponderosa pine forest provides summer range for Arizona grazing livestock. (Photo: U.S. Forest Service)

Predicting Herbage Production from Forest Growth in Arizona Ponderosa Pine

*by Peter F. Ffolliott & Warren P. Clary**

Many empirical relationships have been developed to describe annual herbage production in relation to forest density. These relationships provide a basis for estimating differences in annual herbage production beneath varying forest densities (Ffolliott and Clary 1973). However, while herbage production is a measure of annual yield, expressions of forest density (volume, number of trees, etc.) describe a cumulative production situation at a point in time. This may be unfortunate, as it is often desirable to evaluate these natural resource yields (herbage and wood) on a common time scale. Such evaluations facilitate decision-making relative to which combination of herbage and wood should be produced on an area.

As little work has been directed toward the development of relationships between annual herbage production and annual forest growth, an exploratory investigation was conducted to synthesize such relationships for Arizona ponderosa pine (*Pinus ponderosa*) forests. More specifically, the study was designed to develop relationships between annual herbage production and annual forest growth in the ponderosa pine type existing on volcanic soils along the Mogollon Rim.

Description of Investigation

The source data utilized to satisfy the study objective were obtained from 21 sites located throughout the specified investigation area (Figure 2). On these sites, herbage consisted of perennial grasses, forbs, and half-shrubs. Herbaceous species which predominated on one or more of the study sites include the following.

Arizona fescue
Festuca arizonica
black dropseed
Sporobolus interruptus
blue grama
Bouteloua gracillis
bottlebrush squirreltail
Sitanion hystrix
broom snakeweed
Gutierrezia sarothrae

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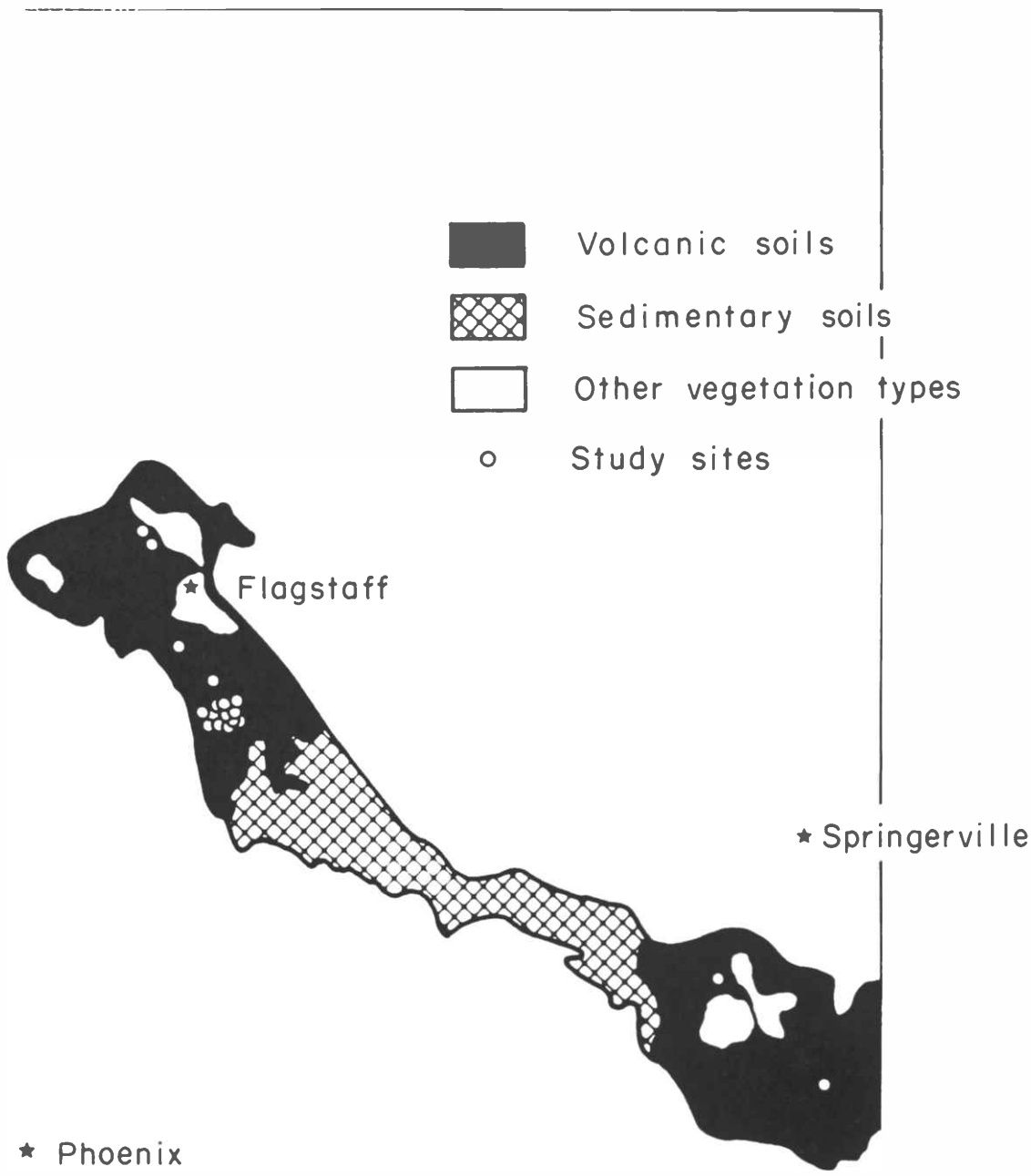

Figure 2. Study sites located throughout the Arizona Ponderosa Pine type of volcanic soils along the Mogollon Rim.

crested wheatgrass
Agropyrom desertorum
intermediate wheatgrass
Agropyron intermedium
Kentucky bluegrass
Poa pratensis
lupine
Lupinus spp.
mountain muhly
Muhlenbergia montana
mutton bluegrass
Poa fendleriana
orchardgrass
Dactylis glomerata

Ponderosa pine, including all age classes in intermixture, dominated the forest overstories, with Gambel oak (*Quercus gambelii*) and alligator juniper (*Juniperus deppeana*) minor species.

The volcanic soils on the study sites ranged in texture from silt-loam to gravel-loam.

Annual herbage production, expressed in pounds per acre, was determined by weight estimate on 25 to 93 9.6-square-feet plots on the study sites (Pechanec and Pickford 1937). Annual forest growth, expressed in cubic feet of merchantable ponderosa pine wood per acre, was assessed by stand table projection (Ffolliott 1965) or Schneider's growth percent formula (Davis 1954). Additionally, average water year (October 1 to September 30) precipitation and mean elevation were determined for all study sites. Water year precipitation corresponds better with the amount of water available for plant growth in a season than does calendar year precipitation. Mean elevation is a possible alternative variable to precipitation when knowledge of precipitation is not available.

Minimum, mean, and maximum of attributes that characterize the study sites are given in Table 1.

Initially, annual herbage production was defined as a function of annual forest growth only. Subsequently, average water year precipitation and mean elevation were included to improve the definition of annual herbage production and annual forest growth within the range of conditions represented by the study sites. As different numbers of years of source data were available among the study sites (1 to 12 years), a weighted regression analysis was used.

Results and Discussion

Annual herbage production decreased with increasing annual forest growth, as was expected. Furthermore, and what was not expected, the mathematical form that these competitive relationships assumed was linear (straight-lined) in all cases. Herbage-forest relationships that have previously been developed with forest density attributes generally assumed nonlinear forms.

The competitive and linear relationship developed between annual herbage production (H) and annual forest growth (G) indicated that, for the data analyzed, the magnitude of a sacrifice that is required in one to achieve a gain in another remains unchanged throughout the range of data; in other words, the rate of "trade-off" is the same. This relationship is

Table 1. Minimum, mean, and maximum of attributes on study sites.

Unit of Measure	*Variable*	*Minimum*	*Mean*	*Maximum*
Annual herbage production	**Pounds per acre**	**131**	**588**	**1540**
Annual forest growth	**Cubic feet per acre**	**0.0**	**18.1**	**63.0**
Average water year precipitation	**Inches**	**17.0**	**22.6**	**28.9**
Mean elevation	**Feet**	**6250**	**7135**	**8800**

$$H = 804 - 14.9\ (G)$$
$$r^2 = 0.88$$

Given knowledge of the annual forest growth, which may often be available from forest resource inventories, this relationship can be evaluated directly to predict annual herbage production.

To provide a basis for predicting annual herbage production from knowledge of annual forest growth within either precipitation or elevational strata, appropriate relationships involving these variables were developed. In essence, these relationships assume families of competitive and linear curves, with each member of a family defining the relationship between annual herbage production and annual forest growth for either a precipitation (P) or elevational (E) stratum (Figure 3). As information describing annual forest growth and precipitation or elevational characteristics can usually be obtained more readily than information describing annual herbage production, these relationships may become useful working tools for the land manager concerned with range resources in Arizona ponderosa pine forests.

The use of the relationships in Figure 3 can best be illustrated by an example. Annual forest growth on a ponderosa pine tract in east-central Arizona is 35 cubic feet per acre. This tract receives approximately 23 inches of precipitation annually, and it is located at 7,200 feet in elevation. Using the graphs in Figure 2, annual herbage production is estimated to be 290 pounds per acre, based on the precipitation variable, and is 300 pounds per acre, based on the elevation variable. The small discrepancy between the estimates of annual herbage production on this site is due, primarily, to statistical variability in the respective regressions. In most instances, such differences will be small. If differences are large, the estimate based on the precipitation variable may generally be assumed more reliable.

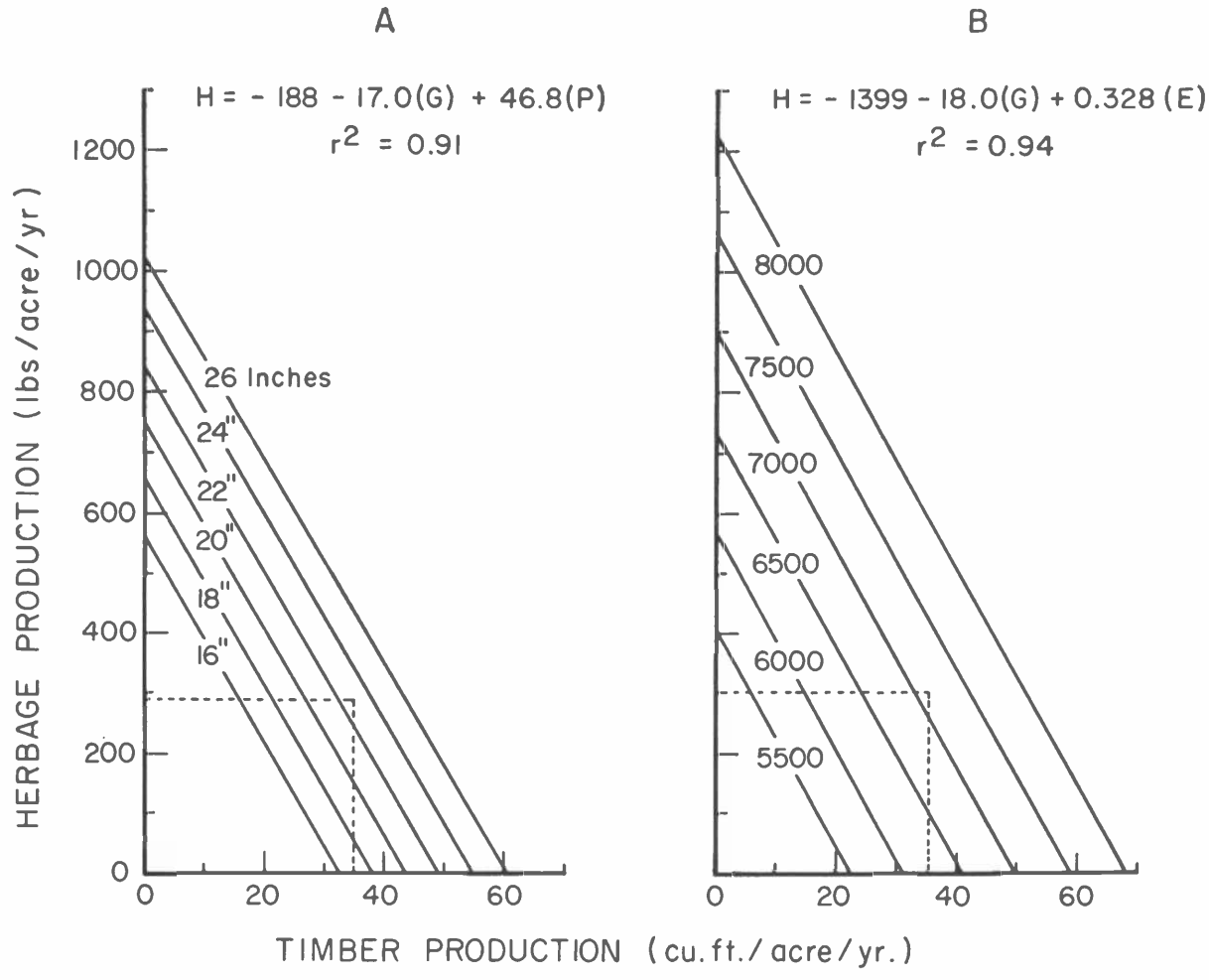

Figure 3. Relationships between annual herbage production and annual production of wood within A precipitation and B elevation strata.

Figure 4. A ponderosa pine forest provides dual utility and production of fiber and forage for Arizona's productive economy. (Photo: U.S. Forest Service)

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