Using Precipitation to Predict Range Herbage Production in Southwestern Idaho

CLAYTON, L. HANSON, RONALD P. MORRIS, AND J. ROSS WIGHT

Abstract

Analyses of 9 years of herbage yield and precipitation data from the Reynolds Creek Experimental Watershed in southwest Idaho show that annual herbage yield can be estimated by the Sneva and Hyder procedure (Sneva and Hyder 1962a, 1962b) at locations other than where their procedure was developed. These analyses did indicate that for sites below 1,680 m, their procedure was more useful when the crop-year precipitation index was based on a variable number of winter and spring months, rather than September through June. For sites above 1680 m, using winter and spring separately in a modified form of their basic equation may improve yield predictions.

Stocking rangelands to fully utilize the annual supply of grazeable forage is not only a difficult task, but it is generally impractical, because of the wide variations in annual yield and the inflexibility of grazing herd size and grazing season. In practice, carrying capacity is usually based on "average" annual herbage production. This results in some overgrazing during below-average production years and under-use of the available forage during above-average production years. In the development of grazing management plans, estimates of average annual herbage production are often unavailable. If annual herbage yields can be predicted from precipitation data with reasonable accuracy, then long-term precipitation records can be used to help establish average annual herbage production for range sites associated with the precipitation data.

Yield prediction equations can also be used to forecast current year's forage production and add at least a degree of flexibility to grazing management, enabling managers to make more efficient use of the total forage resource to provide the year-around nutritional needs of the livestock. Sneva and Hyder (1962a) related herbage yield to crop-year precipitation (September–June) and suggested that current year's yields could be forecast as early as April 1, using the September–March precipitation, plus long-term median precipitation values for April, May, and June. These forecasts could be updated monthly, using actual precipitation data up to the date of forecast and monthly median values for the remainder of the crop year.

Attempts to correlate annual herbage yields with annual precipitation have generally been unsuccessful. This is due primarily to precipitation's variable distribution, and to the fact that range plants generally have the greatest rate of growth during the growing season and little, if any, growth during fall and early winter. Use of seasonal or combinations of monthly precipitation have helped account for the distribution effects and, in many situations, have provided reasonably accurate yield estimates. In Canada, Smoliak (1956) found that May and June precipitation provided good estimates of yield (r=0.86). In North Dakota, Rogler and Haas (1947) correlated April–July precipitation with annual herbage yields (r=0.76). Also in the northern Great Plains, Power and Alessi (1970) and Wight (1978) found that May precipitation was the best single month index of annual herbage production. Sneva and Hyder (1962a) reviewed studies in the intermountain region that indicated winter and spring precipitation were closely correlated to annual herbage production.

In most studies, simple or multiple linear regression analyses, using yield as the dependent variable and precipitation as the independent variable, have been used to develop predictive equations. Such equations tend to be site dependent. To overcome this dependency, Sneva and Hyder (1962a, 1962b) and Sneva (1977) expressed herbage yield and precipitation as ratios of long-term medians. Using data from 13 yield-precipitation series from 3 locations in the intermountain region, they developed an herbage-yield response line based on crop-year precipitation that accounted for 77% of the variation in yields. Another significant innovation of this work was the use of median rather than mean values as a more reliable estimate of the long-term expected values.

The purpose of this study is to verify and extend the procedure developed by Sneva and Hyder (1962a, 1962b) to herbage yield and

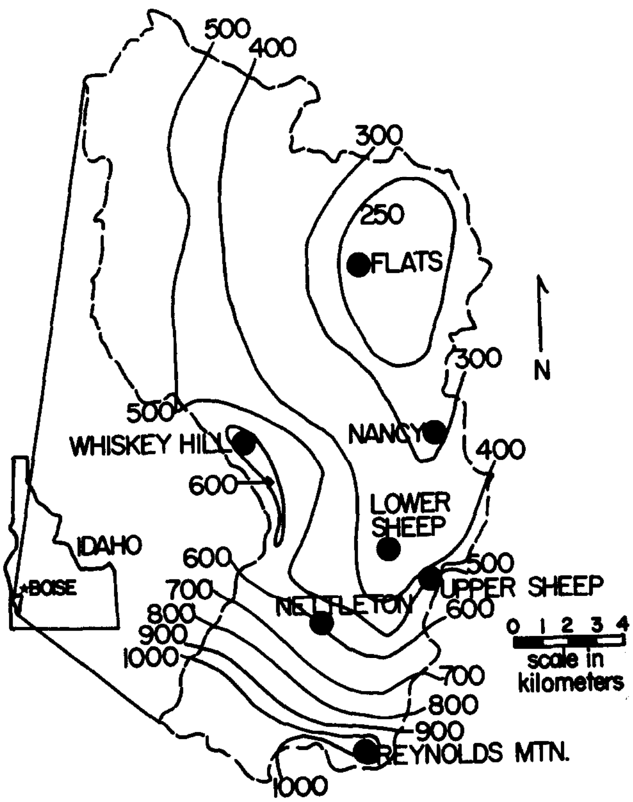

Fig. 1. *Isohyetal map with the locations of the 9 study sites, Reynolds Creek Experimental Watershed, southwest Idaho. Numbers indicate millimeters of precipitation per year.*

Authors are agricultural engineer, hydrologic technician, and range scientist, respectively, Northwest Watershed Research Center, USDA-ARS 1175 South Orchard, Suite 116, Boise, Ida. 83705.

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Table 1. Elevation (m), slope (%), aspect of slope, annual precipitation (mm), vegetative cover (%), and years of record.

Site	Elevation	Slope	Aspect of slope	Precipitation	Vegetation cover	Years of record
Flats	1180	5	N	251	25	8
Nancy Gulch	1400	8	NE	302	25	9
Nettleton	1490	38	W	483	25	9
Lower Sheep Creek	1640	16	NW	347	25	8
Whiskey Hill	1680	15	E	701	50	8
Upper Sheep Creek (South Face)	1860	33	SW	508	25	8
Upper Sheep Creek (North Face)	1860	33	NE	508	50	9
Reynolds Mountain (West)	2090	5	SW	770	25	8
Reynolds Mountain (East)	2070	6	NW	1044	50	9

precipitation data obtained from the Reynolds Creek Experimental Watershed in southwestern Idaho, where herbage yields vary with differences in exposure and elevation.

Methods

Site Description

Nine native range study sites were located on the Reynolds Creek Experimental Watershed in southwestern Idaho (Fig. 1). Site elevation ranged from 1,180 m at Flats to 2,070 m at Reynolds Mountain and the associated average annual precipitation varied from 251 mm to 1,044 mm, respectively (Table 1). Drifting snow accumulations increased plant available water at the Upper Sheep Creek (North Face) and Reynolds Mountain (East) sites. The precipitation distribution was similar for all sites, occurring primarily during winter through early summer (Fig. 2). Soils at the study sites were derived from basalt, granite, or rhyolite; soil textures varied from loam to gravelly loam (Table 2) (Stephenson 1977). The primary plant species at each study site are listed in Table 3. All sites had a dense sagebrush *(Artemisia tridentata* or *Artemisia arbuscula)* cover, except Flats, where shadscale *(Atriplex confertifolia)* was the the major brush species.

Procedure

Annual herbage yields were determined by the double-sampling, weight estimate method described by Wilm et al. (1944). Each year, 2 people estimated the green herbage weight, by species, within 20 randomly located, 9.8-ft^2 circular plots at each site—10 plots inside and 10 plots outside the exclosures. An additional 3 plots inside and 3 plots outside the exclosure were clipped to determine green to dry weight ratios. Sample plots outside the exclosures were caged to protect them from grazing. Yield estimates were made at each site when bottlebrush squirreltail *(Sitanion hystrix)* had reached the seed set stage. Only the nonwoody portion of the brush species was considered annual growth. All yields are reported on an air-dry weight of 12% moisture.

Sneva and Hyder (1962a, 1962b) used precipitation and yield indices as the basic elements in their yield estimations. The precipitation indices were calculated as the individual "crop-year" precipitation (September–June) divided by median crop-year precipita-

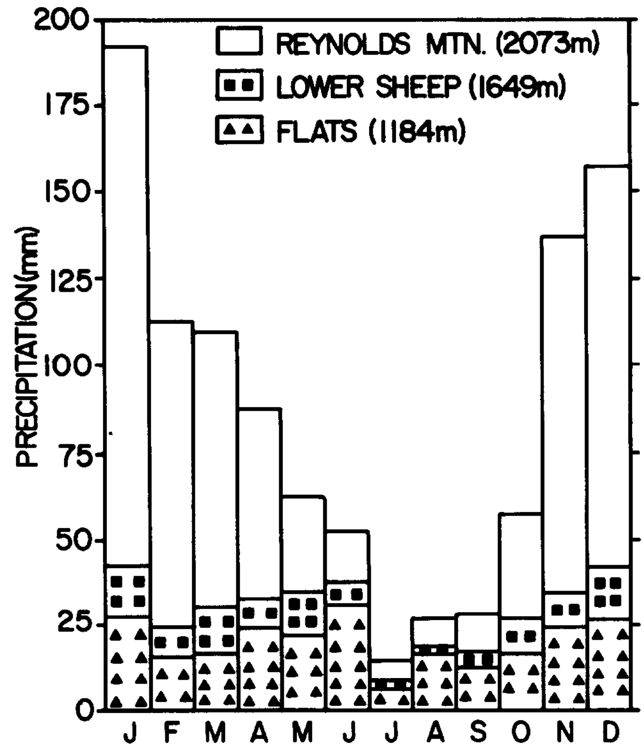

Fig. 2. *Average monthly precipitation at 3 sites.*

Table 2. Geologic material and soil characteristics at study sites.

Site	Geologic material	Soils: Subgroup	Soils: Family	Soils: Series
Flats	Sedimentary	*Typic Haplargids*	Fine loamy mixed, mesic	Nannyton loam
Nancy Gulch	Basalt	*Xerollic Haplargids*	Fine, montmorillonite, mesic	Glasgow loam
Nettleton	Basalt	*Lithic Argixerolls*	Loamy skeletal, mixed, mesic	Reywat-Bakeoven rocky, very stony loam
Lower Sheep Creek	Basalt	*Calcic Argixerolls*	Loamy skeletal, mixed, frigid	Searla gravelly loam
Whiskey Hill	Granite	*Typic Haploxerolls*	Coarse loamy, mixed, frigid	Takeuchi rocky corase sandy loam
Upper Sheep Creek (South Face)	Basalt	*Lithic Argixerolls*	Loamy skeletal mixed, frigid	Gabica very rocky loam
Upper Sheep Creek (North Face)	Basalt	*Argic Pachic Cryoborolls*	Fine loamy, mixed	Harmehl and Demast loam
Reynolds Mountain (West)	Rhyolite	*Pachic Cryoborolls*	Fine loamy, mixed	Bullrey gravelly loam
Reynolds Mountain (East)	Rhyolite	*Pachic Cryoborolls*	Fine loamy, mixed	Bullrey gravelly loam

Table 3. List of primary plant species at study sites.

Plant species	Site 057 Flats	 098 Nancy Gulch	 135 Nettleton	 117 Lower Sheep Creek	 092 Whiskey Hill	 138 Upper Sheep Creek (South Face)	 138 Upper Sheep Creek (North Face)	 176 Reynolds Mt. (West)	 176 Reynolds Mt. (East)
Grasses and Sedges									
Bearded bluebunch wheatgrass *Agropyron spicatum*		X	X	X	X	X			
Slender wheatgrass *Agropyron trachycaulum*							X		X
Big Mountain brome *Bromus marginatus*							X		X
Cheatgrass brome *Bromus tectorum*	X	X	X		X				
Oniongrass *Melica bulbosa*							X		
Idaho fescue *Festuca idahoensis*					X		X	X	X
Nevada bluegrass *Poa nevadensis*							X		X
Sandberg bluegrass *Poa secunda*	X	X	X	X	X	X	X	X	
Bottlebrush squirreltail[1] *Sitanion hystrix*	X	X	X	X	X	X	X	X	X
Needle-and-thread *Stipa comata*					X		X	X	X
Sedges *Carex* sp.							X	X	X
Forbs									
Western yarrow *Achillea millefolium lanulosa*					X		X	X	X
Low pussytoes *Antennaria dimorpha*		X				X			
Rose pussytoes *Antennaria rosea*								X	
Milkvetch *Astragalus* spp.				X		X			
Arrowleaf balsamroot *Balsamorhiza sagittata*					X				
Indian paintbrush *Castrileja* spp.								X	
Bastard toadflax *Commandra pallida*					X				
Hawksbeard *Crepis* spp.					X				
Sulfur eriogonum *Erigonum umbellatum*					X		X		
Clasping pepperweed *Lepidium perfuriatum*	X								
Lupine *Lupinus*			X		X	X	X	X	X
Phlox *Phlox* spp.		X							
Cinquefoil *Potentilla argula convallaria*							X		
Yellow salsify *Tragopogon dubius*			X						
Violet *Viola* spp.							X		X
Shrubs									
Low sagebrush *Artemisia arbuscuta*				X		X			
Mountain big sagebrush *Artemisia tridentata vaseyana*							X	X	X
Wyoming big sagebrush *Artemisia tridentata wyomingensis*	X	X	X		X				

Table 3. Continued.

Plant species	057 Flats	098 Nancy Gulch	135 Nettleton	117 Lower Sheep Creek	092 Whiskey Hill	138 Upper Sheep Creek (South Face)	138 Upper Sheep Creek (North Face)	176 Reynolds Mt. (West)	176 Reynolds Mt. (East)
Shadscale *Atriplex confertifolia*	X								
Mountain low rabbitbrush *Chrysothamnus viscidiflorus lanceolatus*					X	X	X		
Mountain snowberry *Sumonoricarpos oreophelus oreoprelus*							X		X

[1]Indicator species for harvest.

tion; the herbage yield indices were determined, using the same procedure. A regression of the yield indices on the precipitation indices, using data from 13 yield-precipitation series from 3 locations in the intermountain region, resulted in the following equation:

$$Y = 1.11X - 10.6 \quad r = 0.88 \text{ [Sneva and Hyder (1962 a, 1962b)]} \quad [1]$$

where Y is the yield index (%) and X is the precipitation index (%).

Because of the short yield record in this study, estimated medians were calculated for both precipitation and yield, and these values were then used to compute the precipitation and yield indices. The estimated medians were calculated by averaging the middle five values from the 9-year records and the middle four values from the 8-year records. Precipitation data from the 3 sites shown in Figure 2 were used to determine how well the estimated median values, and the range of the 9-year series used in this study compared with the 18-year record available at each site. The estimated median values were all within 9% of the 18-year medians. The range of values used in this study included the year with the least precipitation at each site, and the year that was within 1 or 2 values from the highest value in each series. Similar analysis of a 41-year precipitation record from the U.S. Weather Bureau at Boise, Ida., also supported the validity of the estimated medians, using the same 9-year period as used in the study. The estimated median was within 8% of the 41-year median and range of values included both the highest and lowest values of the series. Based on precipitation alone, this analysis would suggest that the yield data used in this study represent the range of yields that can be expected.

Crop-year indices were calculated for various precipitation periods—i.e., November-April, November-May, etc. Regression techniques were used to relate the crop-year precipitation indices to the herbage yield indices. Except at the Flats site, average herbage yields of the plots in the exclosure and outside the exclosure were not significantly different and were averaged together (Table 4). All tests of significance were done at the .05 probability level.

Results and Discussion

Initial regression analyses showed that there was good correlation between a single crop-year index and the herbage yield index for the 4 data sites below 1,680 m (Table 1). Because the individual equations for the 4 sites below 1,680 m were not significantly different, all the data were combined and a single regression equation obtained for the 4 sites below 1,680 m was:

$$Y_1 = 1.03X_1 + 7.09 \quad r = 0.88 \quad (2)$$

where Y_1 is the yield index (%) and X_1 is the precipitation index (%). The slope of equation [2] was not significantly different from that of Sneva and Hyder (equation [1]), and the residual variances were homogeneous, indicating that the 2 equations were not different. Thus, equation [1] was used throughout the study.

Herbage yield was computed for the low elevation sites using Sneva and Hyder's crop-year precipitation (September–June) and the crop-year precipitation periods selected through regression analysis (Table 4). The results shown in Figure 3 indicate that the best fit crop-year improves yield estimates, but not significantly. Neither of the regression lines shown in Figure 3 was significantly different from the line of equal value, nor were they significantly different from each other.

These analyses indicate that the Sneva and Hyder procedure could be used to estimate yields and that a somewhat improved yield estimate could be made if precipitation data for specific months were available. One reason why the variable length crop-year concept may not have improved the results more was because a preponderance of the precipitation fell during the November through January period; thus, variations in the other monthly amounts do not have the same effect on the computed yields.

Analysis of data from the 5 sites at or above 1,680 m indicated that 2 precipitation-index periods (Table 4) improved herbage yield estimates. The analysis also suggested that each precipitation-index period contributed about 50% to the total yield. Precipita-

Table 4. Average total herbage yield (kg/ha) and crop-year precipitation.

Site	Herbage yield	Harvest dates[1]	Crop-year precipitation period
	Low Elevation Sites		
Flats			
Exclosure	710	May 24	November–April
Grazed	900	May 24	November–April
Nancy Gulch	770	May 29	November–April
Nettleton	1150	June 13	November–May
Lower Sheep Creek	680	June 18	November–May
	High Elevation Sites		
Whiskey Hill	1360	June 30	November-March April–May
Upper Sheep Creek (South Face)	620	June 27	November–March April–May
Upper Sheep Creek (North Face)	1970	July 20	November–March April–June
Reynolds Mountain (West)	730	July 18	November–April May–June
Reynolds Mountain (East)	1550	July 31	November–April May–June

[1]Mean harvest date for years of record.

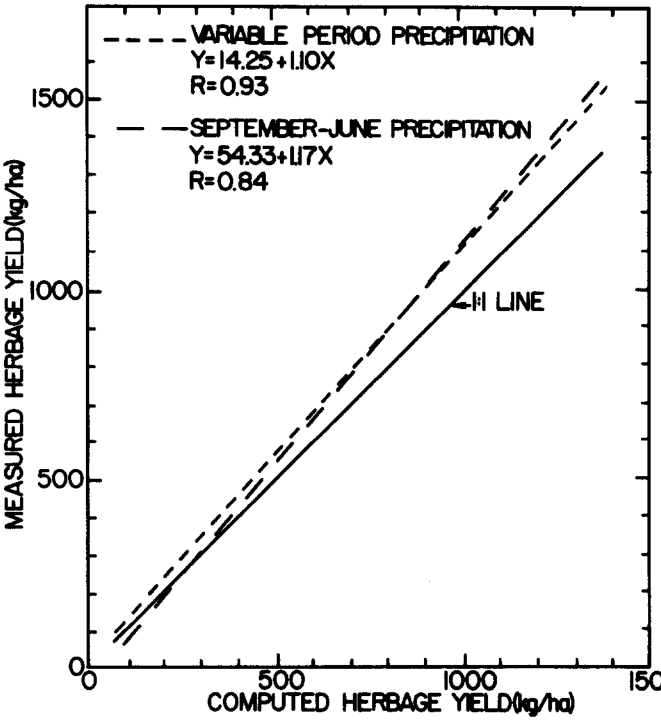

Fig. 3. *Relationship between measured and computed herbage yield using a modified form of the Sneva and Hyder equation where the "crop-year" precipitation varied with location and the Sneva and Hyder equation, for study sites below 1,680 m.*

tion indices were then developed for several precipitation period combinations for each site using a modified form of Equation [1] (see equation [3]). The modified form of equation [1] was then used to determine which precipitation periods best represented each site (Table 4).

This combination of winter and spring precipitation suggests that spring precipitation is more effective for annual growth than winter precipitation, because winter and spring precipitation are given equal weight; but, there was considerably more precipitation during the winter.

The equation developed for the sites at 1,680 m and higher was:

$$Y_h = (X_{h_1} + X_{h_2})\ 0.55 - 10.6 \quad (3)$$

where Y_h is the yield index (%), X_{h_1} is the precipitation index (%) from winter precipitation period, and X_{h_2} is the precipitation index (%) from the spring precipitation. The relationships are shown between measured and computed yields, using equation (3), and equation (1), and equation (1) with the crop-year precipitation periods indicated in Table 4. The slope of the regression lines (Fig. 4) is not significantly different from 1.0 and the intercepts are not significantly different from zero; the regression lines are not different from each other. However, the regression lines shown in Table 4 suggest that a variable length crop-year precipitation index or a 2 crop-year precipitation index (Equation [3]) may improve yield predictions.

As shown in Table 4, the crop-year precipitation periods were November through April, and November through May at the low elevation sites. This difference is most likely associated with the vegetation maturing later in the season as the elevation increases. At the higher elevation sites, such as Upper Sheep Creek, there were 2 precipitation periods that contributed to the herbage yields—one associated with winter precipitation, which was primarily snow, and one associated with spring snow and rain. Precipitation periods at the high elevation sites showed the same trend as those at the low elevation sites with crop-year precipitation extending later into the summer with increasing elevation.

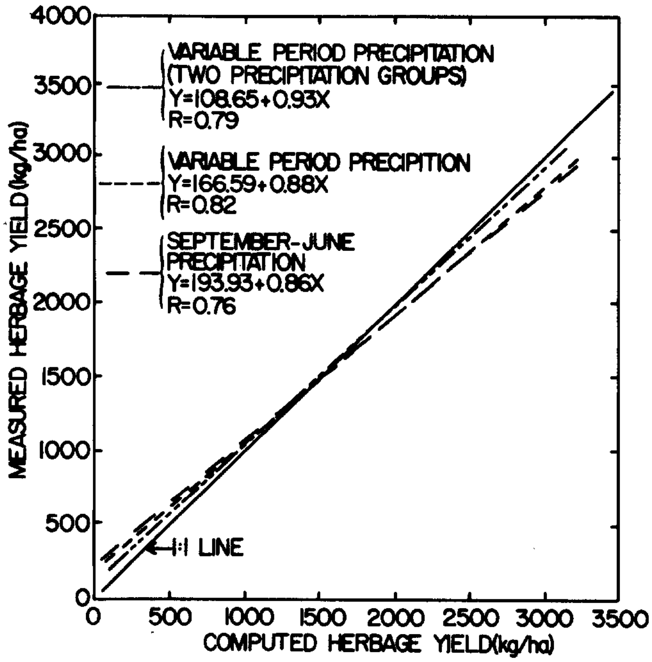

Fig. 4. *Relationship between measured and computed herbage yield to modified forms of the Sneva and Hyder equation, and the Sneva-Hyder procedure for study sites above 1,680 m.*

Summary

The results of this study show that the procedure developed by Sneva and Hyder (1962a, 1962b) is effective over a wide range of annual precipitation and vegetation types. Our study also indicated that at lower elevation sites (below 1,680 m), where there was normally an ephemeral snow cover, results may be improved by using a precipitation index obtained from the months of November through April, or November through May; this depended on site location rather than the crop-year precipitation period Sneva and Hyder used, which was September through June. At sites at or above 1,680 m, a modified form of the Sneva and Hyder equation, using 2 crop-year precipitation periods, may represent the field data more accurately than a single crop-year period. The 2 precipitation periods are likely associated with the fact that snow cover at these sites was generally continuous throughout the winter, and that plant growth is also enhanced by spring and summer rain.

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