Bias in Estimates of Herbage Utilization Derived from Plot Sampling

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Highlight

The ocular estimate by plot method may be biased by the lack of proper weighting procedures. The nature and magnitude of bias is related to sample size, the variability and distribution of yield, and correlation between herbage production and use by livestock. To form unbiased estimates of the population mean, individual estimates must be weighted by production.

Utilization is defined by the Range Term Glossary Committee (1964) as: "the proportion of current year's forage production that is consumed or destroyed by grazing animals." The units of measurement may be height or weight, but for purposes of this discussion the units of measure are restricted to weight.

Expressed in mathematical terms, utilization is then defined as:

\[ X = \frac{U}{P} \]  

where \( X \) is the mean utilization of the population, \( U \) is the total weight of current growth removed by livestock, and \( P \) is the total weight of current production.\(^2\) Normally, utilization is expressed as a percentage, or

\[ X = 100 \left( \frac{U}{P} \right) \]

The ocular estimate by plot method was described by Pechanec and Pickford (1937). According to the authors: "It differs from the general reconnaissance method in that each estimate is made on a plot of such limited area that the entire plot is clearly visible from one point, and percentage utilization is the average of estimates from a series of plots selected at random."

Thus, if \( n \) such plots are examined

\[ \bar{X} = \frac{100}{n} \sum_{i=1}^{n} \frac{u_i}{p_i} \]  

Or

\[ \bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \]  

Equations 3 and 4 constitute an incorrect averaging of percentages if \( p_1 \neq p_2 \neq \ldots \neq p_n \). Proper procedure dictates that

\[ \bar{x} = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{u_i}{p_i} \right) \]  

Or, comparable results can be obtained by weighting \( x_i \) by the corresponding \( p_i \), so that

\[ X = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{p_i x_i}{p_i} \right) \]  

Factors Affecting the Bias

Equations (8) and (4) are unbiased if the \( p_i \) are equal—a condition in which the coefficient of variation is equal to zero, and the production on any given sample unit is equal to the population mean. Since a condition such as this is unknown in populations of natural vegetation, some observations will be over-weighted and some under-weighted by this procedure.

In a normally distributed population, a model for the \( p_i \) may be written as:

\[ p_i = \bar{P} + e_i, \text{ for } i = 1, 2, \ldots, n \]

where the \( e_i \) are normally distributed elements of chance with mean zero and variance \( \sigma^2 \). Then equation (3) may be rewritten as:

\[ \bar{x} = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{u_i}{P + e_i} \right) \]

From equation (8) it is obvious that the value of \( e_i \) determines whether a sample unit is over-weighted or under-weighted. The hypothesis may be made that, since \( e_i \) are normally distributed and \( E = 0 \), the errors tend to counterbalance and average zero. But rarely will \( e_i \) equal zero since sampling error is involved, therefore the estimate \( \bar{x} \) will be somewhat biased.

The assumption of a normal distribution of the \( e_i \) is also open to question. Greig-Smith (1957) suggested that yield data usually show an "approximately" normal distribution. However, he recognized that small samples may result in distribution curves that are strongly skewed. The shape of the distribution curve may vary with the size of the sample unit.

Skewness to the left results in over-weighting an excessive number of low-producing sample units, and tends to introduce a positive bias to the estimate of average utilization. Conversely, skewness to the right results in under-weighting an excessive number of high-producing units and introduces negative bias in the estimate of average utilization.

A third source of bias exists when production and utilization are not independent. If utilization is positively correlated with production, the procedure of Pechanec and Pickford will tend to under-estimate average utilization. Conversely, if utilization is negatively correlated with production, percentage utilization will tend to be overestimated. Cook (1959) found utilization of forage to be heavier on unfavorable sites than on favorable sites. He later found that utilization of some species was correlated with their abundance (Cook, 1962). The nature of the correlation, positive or negative, varied among species.

Application to an Example

Data from a study where both production and utilization of Idaho fescue (Festuca idahoensis Elmer) were measured exemplify the magnitude of bias introduced by the use of (3) as an estimator. The Burgess Experimental Pastures\(^3\) are located in the Bighorn National Forest of north central Wyoming. The pastures consist of three experimental units subject to different livestock management practices. Each experimental unit was first divided into three primary strata corresponding to known intensities of past use by livestock. Then two substrata were selected to conform with soil parent material. Fifteen random sampling units, \( 2 \times 2 \) ft, were selected from each of the substrata.

Sampling within substrata was analogous to simple random sampling. Consequently, the difference in estimates formed by equations (4) and (6) is a

\(^{1}\)Forest Service, U.S. Department of Agriculture, with headquarters at Fort Collins, in cooperation with Colorado State University. Research reported here was conducted at Laramie, in cooperation with University of Wyoming.

\(^{2}\)Parameters are symbolized by capital letters; statistics by lowercase letters.

\(^{3}\)A cooperative study by the Big Horn Permittees Association, the Wyoming Natural Resource Board, the Wyoming Agricultural Experiment Station, and the U.S. Forest Service.
Table 1. Unweighted estimates of percentage utilization ($\bar{X}$) of Idaho fescue and discrepancy (D) as unweighted minus weighted estimates on substrata within the Burgess Experimental Pastures, 1961-62.

<table>
<thead>
<tr>
<th>Experimental unit</th>
<th>Year</th>
<th>D</th>
<th>$\bar{X}$</th>
<th>$\bar{G}^2$</th>
<th>$\bar{S}$</th>
<th>G</th>
<th>S</th>
<th>G</th>
<th>S</th>
<th>G</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>I, Moderate season-long grazing</td>
<td>1961</td>
<td>-0.9</td>
<td>44</td>
<td>0.4</td>
<td>-3.1</td>
<td>25</td>
<td>7</td>
<td>14</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1962</td>
<td>-0.8</td>
<td>27</td>
<td>0.9</td>
<td>2.7</td>
<td>13</td>
<td>41</td>
<td>6</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II, Moderate rotation grazing</td>
<td>1961</td>
<td>-0.4</td>
<td>18</td>
<td>0.3</td>
<td>-5.1</td>
<td>29</td>
<td>50</td>
<td>8</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1962</td>
<td>-0.6</td>
<td>13</td>
<td>0.7</td>
<td>-8.5</td>
<td>13</td>
<td>28</td>
<td>34</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III, Heavy rotation grazing</td>
<td>1961</td>
<td>-0.4</td>
<td>56</td>
<td>2.7</td>
<td>-2.4</td>
<td>53</td>
<td>46</td>
<td>12</td>
<td>48</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>1962</td>
<td>2.1</td>
<td>65</td>
<td>-0.7</td>
<td>-8.0</td>
<td>38</td>
<td>43</td>
<td>31</td>
<td>54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Light, moderate, and heavy refer to relative intensity of past use by livestock.
2 $G^2$ & S refer to the soil parent material of the substrata; granitic and sedimentary, respectively.

A comparison of estimates by equations (9) and (10) forms a measure of the bias present in the primary strata and unit means. In 1961, the bias ranged from 3.5 to -10.4% (average = -2.7%) among the primary strata (Table 2). The estimate of average utilization on the experimental units was biased by 0.4 to -4.6% (average = -1.9%). In 1962, the bias ranged from 0.6 to -12.7% (average = -5.0%) among primary units and -2.8 to -7.8% (average = -4.7%) among the experimental units.

LITERATURE CITED


A Permanent Plot for Measurement of Vegetation Change

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Range and wildlife managers have been dissatisfied generally with techniques for marking permanent plots for future analysis. The authors, faced with the need to measure vegetation change in a low shrub-grassland complex in Wyoming’s Red Desert, designed a sampling frame which can be installed rapidly at permanently marked sampling points. The device was used on key areas of pronghorn antelope winter ranges by employing a cluster sampling technique.

The intent of the design was to enable (1) rapid positioning of the sampling unit, (2) rapid location and placement of a permanent pivot stake, (3) rapid location and placement of a second reference stake, and (4) rapid and accurate relocation of the sampling frame at future dates.

Fig. 1 illustrates both the design and the positions of the permanent marker stakes. A length of steel rod (3/8 x 48 in.) was bent at one end to form a collar with an inside diameter of one inch. The collar was formed to fit tightly, but smoothly, around a piece of one inch pipe, 18 inches in length. These pieces of pipe were driven about one ft into the ground. The six inches protruding above the ground surface served as the pivot stake and receptacle for the collar of the sampling frame.

The sampling frame was also made of steel rod. For our purposes we chose a rectangular frame (1 x 2 ft). It was welded to the rod at the end opposite the collar.

The following procedure was used to locate permanently each sampling frame (side view, Fig. 1). First, a piece of one inch pipe was driven vertically into the ground, using care to prevent damage to the top of the pipe. Secondly, the collar was placed over the section of pipe protruding above the ground surface. Next, the sampling frame was positioned. Finally, a piece of concrete reinforcing rod (3/8 x 12 in.) was driven into the ground directly beneath the point where the “arm” of the sampling apparatus bisected the sampling frame. This rod served as the second reference stake to enable exact relocation of the frame.

Fig. 2. The cluster sampling design.
Influence of Phosphorus Fertilizer Placement on two Nebraska Sub-irrigated Meadows

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Highlight

On two Nebraska sub-irrigated meadows drilling phosphorus fertilizer at a depth of 3 to 4 inches resulted in lower dry matter yields and lower percentages of phosphorus as compared with surface application. By labelling superphosphate (35 lb P/ac) with 32P it was shown that grasses, which constituted the bulk of the forage, took up less fertilizer phosphorus when the latter was drilled in than when applied on the surface.

In general, the sub-irrigated meadows of the Nebraska Sandhills have shown responses to both phosphorus and nitrogen fertilization (Brouse and Rhoades, 1966; Russell et al., 1965). Since fertilizers have been applied on the sub-irrigated meadows almost exclusively by surface broadcasting, a comparison between surface application and drilling of phosphorus fertilizer was made.

Soils and vegetation at the two sites used in this study have been described by Moore and Rhoades (1966). Both soils were sandy but the soil at site 1 was alkaline throughout the profile (pH 7.3 to 8.0 to 40-inch depth) while that at site 2 was mildly acidic (pH 5.9 to 6.7).

Red clover (Trifolium pratense) was present at both sites and alsike clover (T. hybridum) at site 2. Grasses at both sites were dominated by early-maturing species, viz. redtop, Kentucky bluegrass (Poa pratensis) and switchgrass (Panicum virgatum). Prairie cordgrass (Spartina pectinata), bluestems (Andropogon gerardi and A. scoparius), indiangrass (Sorghastrum nutans) and timothy (Phleum pratense) were present at both sites and alsike clover was a lower percentage. In both sites carried some rushes, sedges and forbs.

A randomized block design with four replications was used. Ammonium nitrate (0 and 80 lb N/ac) was applied by broadcasting on the surface. Four rates of triple superphosphate (0, 35, 105, 315 lb P/ac) were applied in bands 8 inches apart either on the surface or drilled in at a depth of 3 to 4 inches. It is possible that the drilled bands occupied more restricted volumes than the surface applied bands. Superphosphate labelled with 32P was used for the 35-lb rate. Treatments were applied in April 1955 and forage harvested in July 1955 and 1956. Small samples of forage were also taken from the 32P-labelled plots on five occasions during the growing season of 1955. Only the effect of drilling superphosphate is reported in this note; the responses of the meadows to surface application of nitrogen and phosphorus fertilizers were similar to those reported by Russell et al. (1965).

Botanical Composition

Forage density measurements were made on May 31, 1955, using the point quadrat method. Overall density of cover was decreased slightly (7 to 8%) by drilling. On site 1 drilled plots showed a higher percentage of legumes than surface application plots and on site 2 a lower percentage. In both cases the response was associated with red clover. Late-maturing grass percentages were lower on the drilled plots (compared with surface banded plots) at both sites while early-maturing grass percentages were higher on the drilled plots at site 2 and were unchanged at site 1.

Drilling killed much vegetation adjacent to the drill-rows. Site 2 had a high proportion of actively-growing, early-maturing grasses. These grasses tillered and occupied much of the drill-row space and also suppressed legume growth. On site 1, however, the lesser proportion of early-maturing grasses allowed the legumes to occupy space provided by the elimination of late-maturing grasses which were still comparatively inactive.

Dry Matter Yields

In the first season drilling produced lower yields compared with surface application (Table 1) due to killing of some plants by the drill. Drilling...