# The Sampling Unit and Its Effect on Saltbush Yield Estimates[1]

**J. Ross Wight**[2]

*Range Scientist, ARS-SWC, Northern Plains Soil and Water Research Center, Sidney, Montana.*

## Highlight

**A 60- by 60-ft plot of Nuttall saltbush *(Atriplex nuttallii)* was completely harvested using 1- by 1-ft sampling units. Yield data for sampling units of various sizes and shapes were obtained by combining contiguous 1- by 1-ft plots. Sampling unit size and shape both had an important effect on sampling efficiency. The coefficient of variation decreased rapidly, as sampling unit size increased, until a sampling unit of about 60 ft² was reached. For the smaller sampling units, the rectangular units generally had a lower coefficient of variation than those that were nearly square. Data are presented showing the relationship between sampling units of various sizes and shapes and (1) their coefficient of variation, (2) the number of samples needed to obtain a yield estimate that is within 20% of the population mean 90% of the time, and (3) the total area needed to be sampled to obtain this yield estimate.**

A major problem facing an investigator in the sampling phase of his research is knowing what is the most efficient sampling unit—size and shape—and the number of samples needed to furnish desired information. Answers to these questions are by no means simple and are different for each individual situation. Characteristics being measured, variability of populations, desired accuracy, and costs are key factors determining sampling procedures.

In fields of science dealing with vegetation, considerable effort has been expended to determine the most efficient sampling procedure for determining yields of specific crops or vegetation types. A common procedure for determining optimum shape and size of sampling units is the use of uniformity trials, also referred to as blank experiments. In this procedure, an area of vegetation is sampled completely with one basic sampling unit. By combining contiguous units in various combinations, data for sampling units of different sizes and shapes can be determined. Variability of sampling units can then be determined. This information is used to help establish the most efficient sampling unit for that particular set of conditions. Evans (1959) defines the most efficient sampling unit as the one supplying desired precision at least expense.

Fewer uniformity trials have been conducted on range vegetation than on cultivated crops. The time and labor involved in running such experiments have limited their use, but this situation has improved with the advent of high-speed digital computers. Statistical analysis of uniformity-trial data now can be readily and economically accomplished. Although application of results of uniformity trials is limited to vegetation types and conditions under which the trials were conducted, the information is valuable for future work conducted under similar conditions. With the aid of high-speed computers, uniformity trial experiments can and should be expanded to other vegetation types until information is available that will be applicable over a wide range of conditions.

Literature dealing with sampling-unit size and shape in relation to sampling native vegetation has been restricted primarily to measurements of frequency, pattern, and plant counts. Relatively little work has been reported relating sampling-unit size and shape to range herbage yields. The work published (primarily for field crops) has shown that, within limits, small sampling units are usually more efficient than large ones and rectangular sampling units are usually more efficient than square or round ones. Three factors play a dominant role in setting these limits: (1) boundary or edge effect of the sampling units, (2) natural distribution characteristics of the vegetation or species under consideration, and (3) comparative costs of the various sampling units.

Yield estimates can be subject to considerable bias due to the boundary or edge effect of the sampling unit (Cochran, 1953; Brown, 1954; Van Dyne et al., 1963; Greig-Smith, 1964). Indication of bias from a boundary effect was not available in this study because the various sampling units were formed from contiguous plots, all of which had been clipped as 1- by 1-ft plots. The boundary effect, however, may be very important and should be considered before selecting a sampling unit.

Small sampling units usually have high variance per unit area. In most cases, variance per unit area decreases as sampling unit size increases. This, one would intuitively expect. Also, as pointed out by Evans and O'Regan (1963), an increase in sampling unit size not only decreases the variance per unit area but observations on them tend to be more normally distributed even when the distribution of the small sampling units is distinctly non-normal. However, it should be remembered that while the distribution of a population of sampling units may be non-normal, means of several of these units will likely have a normal distribution.

Relative efficiency of sampling units of different sizes and shapes is also affected by the uniformity and density of the vegetation being sampled. The variance per unit area increases rapidly for a given sampling unit as the vegetation becomes more sparse and less uniform. In sampling range vegetation, lack of uniformity and density is a particular problem.

Because of economic restrictions, it is not the most precise but rather the most efficient sampling unit that is important. While less total area is usually needed to obtain an adequate sample using small sampling units, costs may be considerably greater than for larger units because of the time required to randomly locate extra sampling units and greater work of handling and weighing them. The optimum sampling unit depends on both statistical efficiency and time efficiency.

As summarized by Evans and O'Regan (1963), the bias, precision, and efficiency of an estimate are affected by the size and shape of the sampling unit and the number of observations. All these factors can be manipulated by the investigator. Thus, for any sampling problem

---

[1] *Published with approval of the Director, Wyoming Agricultural Experiment Station, as Journal Paper No. 319.*

[2] *Research was conducted while author was a Graduate Research Assistant, Plant Science Division, University of Wyoming, Laramie.*

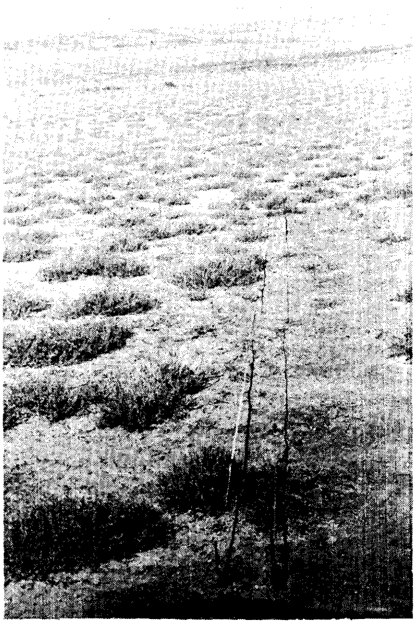

FIG. 1. Nuttall saltbush community showing location of study area.

there exists a combination of size, shape, and number of sampling units that will best fill the needs of the investigator.

This uniformity trial experiment was conducted to investigate the effects of sampling unit size and shape on yield estimates in a Nuttall saltbush community.

**Table 1. The effects of sampling unit size and shape on efficiency of herbage yield estimates of saltbush.**

| Plot size (ft) | S.D. | Coef. var. (%) | No. samples[1] | Area[1] (ft²) | Plot size (ft) | S.D. | Coef. var. (%) | No. samples[1] | Area[1] (ft²) |
|---|---|---|---|---|---|---|---|---|---|
| 1 x 1 | 17.2 | 134 | 121.2 | 121 | 3 x 15 | 220.0 | 38 | 9.8 | 441 |
| 1 x 2 | 30.2 | 117 | 93.2 | 186 | 4 x 12 | 225.4 | 36 | 9.0 | 432 |
| 1 x 3 | 40.1 | 104 | 72.7 | 218 | 5 x 10 | 220.3 | 34 | 7.9 | 395 |
| 1 x 4 | 48.1 | 93 | 58.9 | 236 | 1 x 60 | 202.2 | 26 | 4.7 | 282 |
| 2 x 2 | 53.5 | 104 | 73.0 | 292 | 2 x 30 | 246.7 | 32 | 6.9 | 414 |
| 1 x 5 | 54.8 | 85 | 49.0 | 245 | 3 x 20 | 263.0 | 34 | 7.8 | 468 |
| 1 x 6 | 60.2 | 78 | 41.0 | 246 | 4 x 15 | 265.9 | 34 | 8.0 | 480 |
| 2 x 3 | 70.6 | 91 | 56.4 | 338 | 5 x 12 | 248.4 | 32 | 7.0 | 420 |
| 2 x 4 | 84.6 | 82 | 45.5 | 364 | 6 x 10 | 244.4 | 32 | 6.8 | 408 |
| 3 x 3 | 93.1 | 80 | 43.6 | 392 | 6 x 12 | 245.6 | 26 | 4.8 | 345 |
| 1 x 10 | 79.1 | 61 | 25.5 | 255 | 5 x 15 | 296.4 | 31 | 6.4 | 480 |
| 2 x 5 | 95.9 | 74 | 37.5 | 375 | 4 x 20 | 298.8 | 29 | 5.7 | 456 |
| 1 x 12 | 86.6 | 56 | 21.3 | 256 | 3 x 30 | 318.4 | 27 | 5.1 | 459 |
| 2 x 6 | 105.1 | 68 | 31.3 | 376 | 6 x 15 | 288.8 | 25 | 4.2 | 378 |
| 3 x 4 | 110.6 | 72 | 34.6 | 415 | 5 x 20 | 305.0 | 24 | 3.8 | 380 |
| 1 x 15 | 101.4 | 52 | 18.6 | 279 | 10 x 10 | 293.9 | 23 | 3.5 | 350 |
| 3 x 5 | 125.5 | 65 | 28.5 | 428 | 2 x 60 | 336.6 | 22 | 3.5 | 420 |
| 4 x 4 | 131.7 | 64 | 27.8 | 445 | 6 x 20 | 344.1 | 22 | 3.4 | 408 |
| 3 x 6 | 136.7 | 59 | 23.5 | 423 | 10 x 12 | 331.3 | 21 | 3.2 | 384 |
| 1 x 20 | 114.6 | 44 | 13.4 | 268 | 12 x 12 | 345.0 | 18 | 2.3 | 331 |
| 2 x 10 | 138.4 | 54 | 19.5 | 390 | 5 x 30 | 422.8 | 22 | 3.2 | 480 |
| 4 x 5 | 145.5 | 56 | 21.5 | 430 | 10 x 15 | 386.2 | 20 | 2.8 | 420 |
| 2 x 12 | 150.9 | 49 | 16.2 | 389 | 3 x 60 | 446.3 | 19 | 2.6 | 468 |
| 4 x 6 | 157.5 | 51 | 17.6 | 422 | 6 x 30 | 437.2 | 19 | 2.5 | 450 |
| 5 x 5 | 166.5 | 52 | 18.1 | 452 | 12 x 15 | 458.4 | 20 | 2.6 | 468 |
| 1 x 30 | 145.2 | 38 | 9.5 | 285 | 10 x 20 | 409.7 | 16 | 1.7 | 340 |
| 2 x 15 | 174.8 | 45 | 13.8 | 414 | 15 x 15 | 511.6 | 18 | 2.1 | 472 |
| 3 x 10 | 179.4 | 46 | 14.6 | 438 | 4 x 60 | 544.5 | 18 | 2.2 | 528 |
| 5 x 6 | 176.8 | 46 | 14.6 | 438 | 12 x 20 | 457.4 | 15 | 1.5 | 360 |
| 3 x 12 | 192.1 | 41 | 11.6 | 418 | 5 x 60 | 615.0 | 16 | 1.8 | 540 |
| 6 x 6 | 182.1 | 39 | 10.4 | 374 | 10 x 30 | 543.7 | 14 | 1.4 | 420 |
| 2 x 20 | 198.6 | 38 | 10.0 | 400 | 15 x 20 | 607.7 | 16 | 1.6 | 480 |
| 4 x 10 | 211.2 | 41 | 11.4 | 456 | | | | | |

[1] Number of sampling units and total area needed to insure obtaining a yield estimate that is within 20% of the population mean 90% of the time.

## Study Area and Methods

This study was conducted in a relatively pure saltbush community located in the Big Horn Basin of north-central Wyoming. The saltbush clumps were vigorous with well-defined boundaries (Fig. 1). Fresh-weight forage yield of saltbush in this community was approximately 1,200 lb/acre. A plot 60 by 60 ft was located in a representative area of the saltbush community. During the month of October 1964, fresh-weight yields of saltbush were determined for each square foot in the plot. The saltbush was clipped approximately 2 inches above ground.

Data for sampling units of various sizes and shapes were generated by combining contiguous square-foot sampling units into desired combinations. The possible combinations were limited by the number of integer factors of the number 60. Formation of sampling units and calculation of the coefficient of variation for each set were done with a high-speed computer. Number of sampling units necessary to obtain a yield estimate that would be within 20% of the population mean with a 90% probability was also calculated on the same computer program. The number of sampling units was determined from the relationship $n = t^2s^2/d^2$ (Steel and Torrie, 1960) where $n$ = sample number; $t$ = 1.645; $s^2$ = variance of each sampling unit; $d$ = one-half the acceptable yield interval, which in this case was ±20% of the population mean. Two sets of data were obtained by first forming the sampling units with the long axis of the units extending in an east-west direction and then in a north-south direction. Because there was no significant difference between the two sets of data, they were combined and data presented here are the average of both. Coefficients of variation were calculated as the standard deviation of the sample, times 100, divided by the sample mean. Thus, the coefficients of variation are comparable for the different sampling units.

## Results and Discussion

Size of sampling unit had a pronounced effect on the coefficient of variation (Table 1). Increasing the sampling unit from 1 to 60 ft² decreased the coefficient of variation from 134 to about 30%. Further increases in sampling unit size had little effect on the coefficient of variation.

The high coefficients of variation associated with small sampling units are a reflection of vegetation type.

With saltbush growing in clumps averaging about 2 ft in diameter and with a total ground cover of about 21%, the small sampling units often fell on bare ground (zero yield). Zero yields coupled with maximum yields obtained when the sampling unit fell in the middle of a saltbush clump resulted in high variance and high coefficient of variation.

The advantage of long, narrow sampling units over those which were approximately square was evident in smaller units (Fig. 2), but this advantage disappeared when the short side of the sampling rectangle exceeded about 5 ft. This effect of sampling unit shape on the coefficient of variation was related to the pattern of distribution of saltbush vegetation in the same manner as was sampling unit size.

Efficiency of a sampling unit is a function of its variability and the costs involved in obtaining it. The data in Table 1 indicate that the 1- by 1-ft units had the highest coefficient of variation, but they would still be the most efficient sampling units if sampling cost were directly proportional to total area sampled. In this study it was necessary to harvest a minimum area of 121 $ft^2$ using 1- by 1-ft sampling units to ensure having a yield estimate that would be within 20% of the population mean at least 90% of the time. The same precision was obtained using 26 units 1 by 10 ft or 13 units 1 by 20 ft, both with a total area of 260 $ft^2$. The question to be resolved is which would cost the most to harvest—121 units 1 by 1 ft, 26 units 1 by 10 ft, or 13 units 1 by 20 ft. The answer to this question will vary with methods of locating and harvesting sampling units. Under normal conditions it is generally less expensive to locate and clip one large unit than several small units having the same total area. Cost studies for various size sampling units must be made before the most efficient sampling unit can be determined.

Another factor that might be considered in selecting a sampling unit is the total area being studied. In a large area encompassing sites with varying levels of productivity, random distribution of a few large sampling units could result in a proportionally high representation of one level of productivity. A larger number of smaller units would tend to give a better representation of the total area.

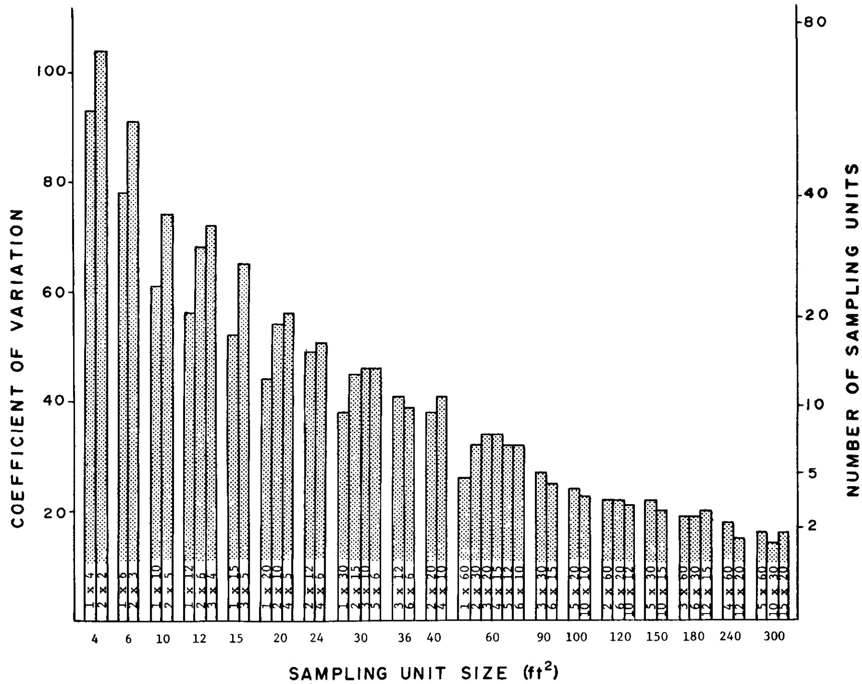


FIG. 2. Relationship between sampling unit shape and size and the coefficient of variation and number of sampling units necessary to obtain a yield estimate that is within 20% of the population mean 90% of the time.

While results of this study do not indicate the most efficient sampling unit for a specific circumstance, they do provide basic information which is necessary in selecting a suitable sampling unit for estimating forage yield of Nuttall saltbush and species having similar growth patterns.

## LITERATURE CITED

BROWN, D. 1954. Methods of surveying and measuring vegetation. Commonwealth Bureau of Pastures and Field Crops Bull. 42. Hurley, Berks, England. 223 p.

COCHRAN, W. G. 1953. Sampling techniques. John Wiley and Sons, Inc., New York. 330 p.

EVANS, T. C. 1959. General appraisal of statistical problems and needs. *In* Techniques and methods of measuring understory vegetation. Proceeding of a symposium at Tifton, Ga., Southern Forest Exp. Sta. and Southeastern Forest Exp. Sta. p. 146-151.

EVANS, T. C., AND W. G. O'REGAN. 1963. Sampling problems in the measurement of range vegetation. *In* Range research methods. U.S. Dep. Agr. Misc. Pub. 940. p. 54-60.

GREIG-SMITH, P. 1964. Quantitative plant analysis. 2nd Ed. Butterworths, Inc., Washington, D.C. 256 p.

STEEL, R. G. D., AND J. H. TORRIE. 1960. Principles and procedures of statistics with special reference to the biological sciences. McGraw-Hill Book Co., Inc., New York. 481 p.

VAN DYNE, G. M., W. G. VOGEL, AND H. G. FISSER. 1963. Influence of small plot size and shape on range herbage production estimates. Ecology 44:746-759.