Measuring Rangeland Production

I. **Definition** = Several different ecosystem attributes could be considered "production"

A. Gross Primary Production = Total amount of organic matter in an ecosystem including above ground (leaves and stems) and below ground (roots) biomass. Also sometimes referred to as Net Primary Production.

B. Biomass = Total weight of living organisms (per unit area), including plants and animals. (In range science, biomass usually refers to plant mass only)

C. Phytomass = Total weight of plant biomass in and ecosystem (per unit area).

D. Standing Crop = The amount of biomass at a given time. Usually refers to the amount of above-ground plant biomass.

E. Peak Standing Crop = The maximum amount of standing crop observed during a given year.

F. Herbage = Above ground biomass of herbaceous plants.

G. Browse = The portion or amount of woody plants available for animal consumption. Usually current season's growth of twigs and leaves.

H. Mast = Fruits, nuts, and seeds produced by woody plants and used as food by animals.

I. Forage = Herbage or browse which is potential food for animals.

II. **When to Measure Production Attributes**?

A. Phytomass, standing crop, or forage are most often measured to set stocking rates or assess an ecosystem's capability to support a specific number of wildlife.

B. Many scientists believe that the relative production of different plant species is the best measure of these species' role in the ecosystem. Therefore, some measure of production is often used in dominance studies.

C. Estimates of phytomass (especially herbage) are often necessary to assess hydrologic properties of a site.

D. It is necessary to measure herbage when assessing the feasibility and potential behavior of a prescribed fire.

E. Some measures of production may also be necessary to assess the value of a site for wildlife habitat; for example, the amount of herbage affects the value of a site fro upland game birds.

III. **Advantages**

A. Most production attributes are strait-forward, easy to interpret, and can be objectively measured.

B. Production can be directly measured with little training, although, it is time consuming.

C. Production can be easily measured and therefore the accuracy of estimation techniques can be easily tested. In contrast, cover is easy to estimate, but direct measures of cover are very difficult to make and therefore the accuracy of cover estimates are seldom examined.

D. Production is considered a good measure of plant dominance on a site because it reflects the amount of sunlight, water and minerals a plant is able to capture and turn into biomass.

IV. **Disadvantages**:

A. Collecting production data can be very time and labor consuming. Cover, frequency and density are generally more quickly estimated.

B. In many rangeland areas, the variability between quadrats and the accuracy of estimating production within individual quadrats necessitates that many quadrats be sampled to detect differences between sites or years.

C. Biomass and Gross Primary Production are rarely measured in rangeland studies because it is very difficult (and usually impractical) to measure below ground biomass.

D. Biomass in rangeland studies generally refers to “phytomass” only because weight of animal mass in a given area is extremely difficult to measure.

E. Peak standing crop may be difficult to measure in ecosystems with a large variety of species because each species will generally reach it’s peak phytomass at a different time of year. For example, rangeland regions in the Central Great Plains may have about equal proportions of cool season and warm season grasses. However, the cool season grasses will peak out in June while the warm season grasses will not reach peak biomass until July or August. When should peak standing crop be measured in these situations? As a compromise, peak standing crop is generally measured at the end of the growing season.

F. When measuring annual production, current year’s growth can be hard to separate from previous year’s growth.

G. Seasonal and annual climatic fluctuations affect biomass, therefore, production is not a suitable measure for long-term trend studies that compare data taken in different years. Density, frequency, and basal cover are less susceptible to yearly variation because of climatic fluctuations.

H. Standing crop can also be altered by herbivore utilization. Therefore, exclosures are usually necessary to measure this attribute. Additionally, up to 25% of the phytomass can be removed by insects or rodents that cannot be easily excluded from study areas.

V. **Estimation of Herbaceous Biomass**

A. Direct Measurement Methods

1. Harvest or Clip-and-Weigh Methods:

a. Clipping vegetation to ground level and then weighing it is the most direct and objective way to measure herbaceous biomass.

b. Clipping can be accomplished with grass shears, sheep shears, power grass shears, sickles, and hand lawnmowers equipped with grass catchers.

c. Though “clip-and-weigh” methods are highly accurate, they are very time consuming. Therefore, harvest techniques are usually combined with indirect estimation techniques in methods known as “double sampling”.

d. Before clipping, the field technician must clarify which plants with a plot will be clipped.

(1) All plants or just forage plants?

(2) Current season’s growth or total standing crop?

(3) All plants rooted in the plot or those that occur within or above the perimeter of the quadrat? Most researcher believe that plants within or in a vertical projection above the perimeter should be sampled. However, in grasslands, it is usually easier to clip all stems rooted in the plot and not worry if they hang into or out of the plot.

(4) Will species be clipped and weighed separately, will plants be clipped by functional group (e.g., cool season grasses, annual forbs, etc.) or will all plant be clipped and weighed?

2. Weighing and Drying Harvested Material:

a. The weight of plant material includes inter- and intra-cellular water and external water such as dew and precipitation. Therefore, the weight of freshly harvested plant material is highly variable and depends on recent weather, atmospheric conditions, and the water status of the plant. For more meaningful interpretation of production, phytomass is expressed on an air- dried or oven-dried basis.

b. Generally, the weight of all fresh, or “green”, samples are weighed in the field and then a subset of these samples are brought back to the lab to be oven-dried. Alternatively, all the samples can be collected and brought back to the lab. In this case, it is not necessary to weight the samples in the field.

c. Once a sample is dried the **% dry matter** = **(Dry Wt./Fresh Wt.) *100** where the “*Dry Wt.*” is the weight of the sample after oven drying and “*Fresh Wt.*” is the weight of the sample recorded in the field.

d. **Recommended Drying Procedure:**

(1) Dry sample within 24 hours of clipping. The sooner the better.

(2) Place samples (in paper bags) in a forced-air oven 60-70° C.

(3) Most samples will take 24-48 hours to dry.

(4) To determine if a sample is dry, a few bags can be removed from the oven, weighed and returned to the oven. A few hours later (4-8 hours) the bags can be removed again and weighed. Samples are dry when no changes in weight occur between reweighing. This is called "drying to a constant weight".

(5) Once a sample is dried, it must be stored in a dry place or it will absorb atmospheric moisture and gain weight.

(6) Air-dried samples are sometimes used to compare production. If an oven is not available and if samples are collected in a very dry environment (where molding is unlikely), the samples can be placed in a dry warm place to dry-out over several days to reach an "air-dried" weight. (A drying room can be established simply by turning the heat up in a room.)

e. Estimated Dry Weights: If it is extremely difficult to dry samples, a few book values or "rules-of-thumb" can be used to covert fresh mass to dry mass:

Dry Matter Content of green forage (For more detail see Dry Matter Conversion Table. Exhibit 4-2 in Chapter 4 of National Range And Pasture Handbook http://www.glti.nrcs.usda.gov/technical/publications/nrph.html)

(1) Grass:

(a) before heading	35-30% dry matter
(b) headed out	35-40%
(c) after bloom	45-50%
(d) mature seeded	55-60%
(e) leave dry/stem partly dry	80-85%
(f) apparent dormancy	90-95%

(2) Forbs:

(a) very lush	15-20%
(b) mature, seed-stage	35-40%
(c) seed rip, leaves drying	60%
(d) dry and dormant	90-100%

(3) Shrubs (deciduous):

(a) lush new leaves	20-35%
(b) older, full-sized leaves	50%

(4) Shrubs/Trees (evergreen):

(a) lush new leaves	55%
(b) older, full-sized leaves	65%

B. Indirect Measurement Methods

1. Double Weight Sampling

a. This procedure basically requires that the field technician estimate the weight of several plots and then clip a few plots to determine the accuracy of estimates then adjustments to estimated weights can be made.

b. The advantage of double sampling is that it takes a lot less time to estimate the weight in a plot than it does to clip a plot. Therefore, many more plots can be examined in a pasture or management unit.

c. To accurately estimate the amount of phytomass in a plot, the observer must spend time training. The training procedure basically entails weighing representative units of a plant and establishing an “eye” for what 10-, 20-, or 50- grams of forage looks like.

d. The accuracy of the observer’s estimate depends on:

(1) The experience of the observer. Well trained technicians with a good deal of field experience can estimate the amount of forage in a plot with little error.

(2) The alertness of the observer. Accurate estimation requires significant concentration. Accuracy often decreases at the end of the day when observers are tired, hot, or hungry.

(3) The vegetation type. Some plant types are simply easier to estimate than other. For example, bunchgrasses are often easier to estimate than sod-forming grasses.

e. How many plots should be clipped? In this technique a number of plants will be estimated and several will be clipped. The number of plants to be clipped depends primarily on the variation in phytomass from plot to plot and the accuracy of the observer’s estimates. There are several formulas that can give an idea of how many plots need to be clipped (Bonham 1989, pages 202-206). A good rule of thumb is to harvest at least 1 plot for every 7 estimated. Further guidelines include:

(1) Enough quadrats should be clipped so that some quadrats represent the least amount of phytomass likely to be encountered on the site and some quadrates represent the greatest amount of phytomass likely to be encountered on the site.

(2) Each quadrat should be estimated first and then a random procedure (e.g., a coin toss or random generator in a computer) should be used to determine if the plot needs to be clipped. If this is not done, the observer will tend to estimate the plots that need to be clipped more carefully than those that are not going to be clipped.

(3) Ideally, the observer should never see the weight of the clipped plot or the observer will adjust the weights of subsequent plots. In double sampling methods, it is more important to be precise and consistent than it is to be accurate. However, the practice of predicting, clipping, then weighing does improve the accuracy of an observers guesses over time.

(4) There is disagreement over whether an observer should try to estimate dry weight or fresh weight in a plot. Generally, fresh weight is estimated because it seems more relevant in the field.

f. Adjusting estimated weights with double sampled plots (estimated and clipped plots).

(1) A short-cut procedure based on the average difference between the estimated and clipped plots, is given in the Interagency Handbook, Sampling Vegetation Attributes, pages 106 to 107.

(2) The preferred procedure is to conduct a regression analysis. All double sampled plots are used to create a regression line: $y = a + bx$

(a) y is the clipped weight of a plot

(b) x is the estimated weight of a plot

(c) a is the y-axis intercept (a constant that is added to each estimate)

(d) b is the slope of the regression line

(e) Computer calculation. Most computer spreadsheet programs can develop a regression line.

(f) Hand calculation. The procedure for calculating a regression line can be found in most basic statistics text books. Attached is a worksheet for calculating a regression line.

(g) Adjust estimated plots. After a regression line is established, all of the estimated weights can be adjusted to improve the accuracy of the guesses.

Once again, $y = a + bx$

with "y" being the adjusted weights and "x" the estimated weights

For example:

If your calculated regression line is: y = -20 + 1.5x

And, your estimated value (x) is 30 g/plot

Then y = -20 + (1.5*30) or your adjusted value is 25 g/plot

(h) Put weights on dry weight basis. The clipped weights and the adjusted weights should then be put on a dry weight basis with the procedure discussed above under the "harvest method".

(i) Convert weight to meaningful units. When all weights are adjusted and averaged the result will be phytomass in a small area. Most calculations need to be converted to lbs/ac or kg/ha to be meaningful. Bohnam (1989) includes a table on page 318 (Table A.2) that lists constants for converting "weight/small area" to "weight/large area".

2. Capacitance Meter - is a device with finger like electrodes that when placed over a plot measure the amount of electronic capacitance in the plot.

   a. Electronic capacitance is related to biomass because capacitance is directly affected by height and density of forage in a plot.

   b. Electronic capacitance must be converted to biomass with a double sampling procedure like that outlined above. In the regression equation the capacitance becomes the "estimated" value.

   c. Capacitance meters are generally observed to work well in grasslands but not as well in shrublands.

   d. The capacitance meter is heavy and difficult to transport across rough pastures.

   e. Capacitance can be affected by plant moisture and ambient conditions.

3. Rising Plate Meter - is a devise consisting of a weighted disk on a measuring pole.

   a. At various places in a pasture the plate is allowed to fall freely into the vegetation. The height of the plate on the pole is recorded.

   b. Plate meter readings are related to biomass because how far the disk falls depends on the height and density of the vegetation in the plot.

   c. The rising plate meter has been shown to work well in estimating herbaceous vegetation on relatively productive sites.

   d. It is simple to use, easy to transport, and often yields estimates of biomass production as accurately as the capacitance meter or height:weight correlations.

   e. The rising plate meter is also a double sampling technique were some of the plots must be clipped to calibrate the meter. The height must be converted to biomass with a double sampling procedure like that outlined above. In the regression equation the height becomes the "estimated" value.

4. Other indirect double sample techniques. Many additional techniques have been developed to measure some plant attribute and use it to estimate biomass. In

each case the measured attribute must be converted to biomass with a double sampling approach such as that outlined above. The plant attributes include:

a. Spectral reflectance - where spectroreflectance curves are measured with a spectrophotometer and then related to biomass.

b. Cover, height, and density estimates have also been used to estimate biomass and have been found reliable in some vegetation types.

5. Comparative Yield Techniques - It is often easier to rank the production in a quadrat relative to other plots than it is estimate that actual weight of phytomass in the plot. A series of plots that represent ranked values can then be clipped and used to adjust the ranks to phytomass estimates. If done correctly, ranking of plots can give estimates of phytomass as accurate as those obtained with double-weight sampling.

   a. This procedure is outlined in the Interagency Handbook - "Sampling Vegetation Attributes" on pages 116-122.

   b. Establishing referent plots. The observer examines the site to be assessed and selects a plot that represents the lowest amount of forage likely to be encountered in a plot and ranks this plot as 1. A plot representing the highest amount of forage likely to be encountered in a plot is ranked as 5 and plots representing intermediate values of 2,3, and 5 are also selected.

   c. Assessing additional plots. After examples of ranks 1-5 are well in the mind, the observer places plots throughout the study area and ranks these plots from 1 to 5. (Ranks can include fractions of a rank, e.g., 2.5 or 3.5)

   d. Calibration of ranked plots. When assessment of the study area is completed, the referent plots are clipped, weighed, and samples are collected for drying. A regression analysis can then be preformed to relate ranks (x-variable) to clipped weight (y-variable).

   e. Conversion of ranks to biomass. The regression equation is then applied to the ranked plots to obtain estimates of phytomass.

6. Photo Reference Guides are being developed in several areas to aid in the visual estimation of the amount of forage in a plot. A photo guide consists of pictures of plots labeled with the amount of forage each contains. Photo guides can be used in double weight sampling or comparative yield techniques to improve the accuracy of estimates. However, photo guides are most often used to just get a "ball park figure" of standing crop.

VI. **Estimating Woody Biomass**.

A. Direct and Destructive Methods of Estimation.

1. Harvest methods - Woody plants can be harvested and weight just as herbaceous samples can.

   a. However, clip-and-weigh methods are rarely the sole way of estimating woody mass because it is very time consuming and because woody plants take much longer to recover from harvesting than do herbaceous plants.

   b. Generally, only the browse portion of woody plants is harvested. However, the whole plant can be collected and the current season’s growth can be separated from the clipped biomass.

B. Indirect Methods of Estimation:

1. Reference Unit:

   a. A small unit of a plant (such as an average sized branch) is designated as the reference unit and clipped from the plant.

   b. A reference unit should be 10-20% of the foliage weight of the average plant.

   c. The reference unit is then held up against plants for which phytomass estimates are required. The number of reference units in other plants of interest is recorded.

   d. The weight of current season’s growth or total mass of the reference unit is then determined.

   e. The weight of estimated plants = number of ref. units * wt of the ref. unit.

   f. The techniques works well for some shrubs, but is not well suited for compact, dense, unsegmented growth forms.

   g. One disadvantage of this technique is that it is not a double sampling technique therefore the accuracy of the estimate is never determined.

2. Double Sampling Techniques:

   a. Weight Estimate Double Sampling. As with herbaceous plants, an observer can develop the skill necessary to estimate the amount of phytomass in shrubs. However, it is much more difficult for most shrubs than it is for herbaceous plants. Therefore, visual estimation with correction through double sampling is seldom used.

b. Crown Area -

(1) The crown area of a plant is often highly correlated to current season's growth biomass. Therefore, crown area can be used in double sampling techniques

(2) The widest dimension of the plant is recorded as dimension 1 (D1).

(3) The dimension perpendicular to DI is dimension 2 (D2).

(4) Crown area = $\pi * D1 * D2$

(5) A sub-sample of the measured plants are then clipped and weighed.

(6) A regression analysis is completed, as outlined above, with crown area as the x-variable and clipped weight as the y-value.

c. Crown Volume or Dimension Analysis.

(1) The crown volume of a plant is also often highly correlated to current season's growth biomass. Therefore, the 3-dimensional volume of a plant can be used in a double sampling technique.

(2) The dimensions measured to estimate crown volume depends on the 3-dimensional shape that best describes the plant (e.g., inverted cone, half spheroid, sphere). Most shapes require the measurement of the diameter and some require measurement of height.

(3) A sub-sample of the measured plants are then clipped and weighed.

(4) A regression analysis is completed, as outlined above, with crown volume as the x-variable and clipped weight as the y-value.

d. Additional Double Sampling Techniques

(1) Basal Diameter or Stem Diameter - for many shrubs a measure of basal diameter (or diameter of central stem) is highly correlated with browse or leaf biomass and can be used in a double sampling technique.

(2) Twig Measurements - the number of basal stems or the average diameter of basal stems is also highly correlated to browse biomass in many shrubs. In a double sampling method, the number or diameter of basal stems is measured for many shrubs and a sub-sample of these shrubs are clipped and weighted.

(3) Capacitance meters - for fairly dense, well defined shrubs, capacitance meters may be used in much the same way as they are used for estimating herbaceous biomass (above).

3. Obtaining biomass of shrubs per unit area

   a. The methods for obtaining shrub biomass listed above are used to determine the biomass of individual plants.

   b. In order to estimate the biomass of shrubs or browse per acre or per hectare the technician must combine individual plant measurements with cover or plant density estimates.

   c. Belt transects or circular chain plots can be easily adapted to shrub measurement techniques where the biomass of each plant in a plot is measured or estimated

   d. A sub-sample of plants on a site can be harvested to gain estimates of shrub or browse biomass per unit area.

Important References for Estimation of Rangeland Production

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