INVENTORY AND MONITORING
Technical Reference 1734–7

Ecological Site Inventory

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"An ecological site is a distinctive kind of land with specific physical characteristics that differs from others kinds of land in its ability to produce a distinctive kind and amount of vegetation."

–National Range and Pasture Handbook

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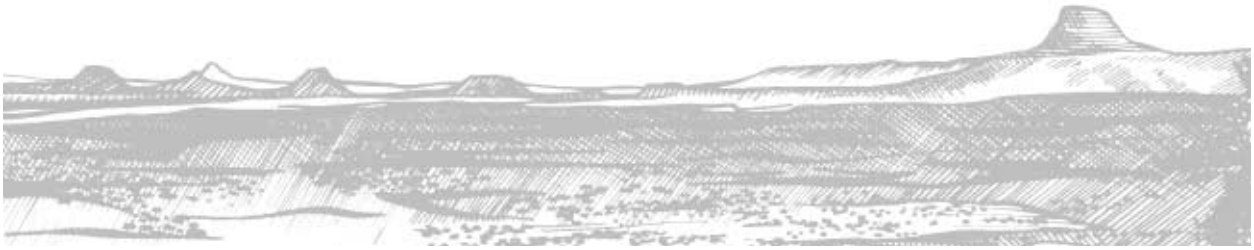


Chapter 4 - Production Data

Aboveground Vegetation Production

ALL PRODUCTION AND COMPOSITION data collected are based on weight measurements. Weight is the most meaningful expression of the productivity of a plant community or an individual species.

Production is determined by measuring the annual aboveground growth of vegetation. Some aboveground growth is used by insects and rodents, or it disappears because of weathering before production measurements are made. Therefore, these determinations represent a productivity index. They are valuable for comparing the production of different rangeland ecological sites, plant species composition, and similarity index.

Comprehensive interpretation of plant production and composition requires that data be representative of all species having measurable production. Rangeland and other grazing lands may be used or have potential for use by livestock and wildlife, as recreation areas, as a source of certain wood products, for scenic viewing, and for other soil and water conservation purposes. The value of plant species for domestic livestock often is not the same as that for wildlife, recreation, beautification, and watershed protection. Furthermore, the principles and concepts of rangeland ecological site, similarity index, and other interpretations are based on the total plant community. Therefore, interpretations of a plant community are not limited solely to species that have value for domestic livestock.

The procedures and techniques discussed in this section relate primarily to rangeland. Most of them, however, also apply to grazeable forest and native or naturalized pasture. Changes or modifications in procedures required for land other than rangeland are described.

Total Annual Production

The total aboveground production of all plant species of a plant community during a single year is total annual production. Total annual production includes the aboveground parts of all plants produced during a single growth year, regardless of accessibility to grazing animals. An increase in the stem diameter of trees and shrubs, production from previous years, and underground growth are excluded.

Production for Various Kinds of Plants

The Vegetation Production Worksheet (Appendix 4) can be used to record production data on individual plots.

Herbaceous Plants

These plants include grasses (except bamboos), grasslike plants, and forbs. Annual production includes all aboveground growth of leaves, stems, inflorescence, and fruits produced in a single year.

Woody Plants

Determining production of trees and large shrubs by harvesting portions of stands is time consuming and impractical. Research scientists are devising methods for calculating current production of some species on the basis of measurements of such factors as crown width or height and basal area. These data are helpful in estimating the annual production of trees and large shrubs. (Appendix 5 provides an example of estimating annual production on Utah Juniper.)

Deciduous Trees, Shrubs, Half-shrubs, and Woody Vines

Annual production includes leaves, current twigs, inflorescence, vine elongation, and fruits produced in a single year.

Evergreen Trees, Shrubs, Half-shrubs, and Woody Vines

Annual production includes current year leaves (or needles), current twigs, inflorescence, vine elongation, and fruits produced in a single year.

Yucca, Agave, Nolina, Sotol, and Saw Palmetto

Annual production consists of new leaves, the amount of enlargement of old leaves, and fruiting stem and fruit produced in a single year. Until more specific data are available and if current growth is not readily distinguishable, consider annual production as 15 percent of the total green- leaf weight plus the weight of current fruiting stems and fruit. Adjust this percentage in years of obviously high or low production.

Cacti

Prickly Pear and Other Pad-forming Cacti

Annual production consists of pads, fruit, and spines produced in a single year plus enlargement of old pads in that year. Until more specific data are available and if current growth is not readily distinguishable, consider annual production as 10 percent of the total weight of pads plus current fruit production. Adjust this percentage for years of obviously high or low production.

Barrel-type Cactus

Until specific data are available, consider annual production as 5 percent of the total weight of the plant, other than fruit, plus the weight of fruit produced in a single year.

Cholla-type Cactus

Until specific data are available and if current growth is not readily distinguishable, consider annual production as 15 percent of the total weight of photosynthetically active tissue plus the weight of fruit produced in a single year.

Methods of Determining Production

Production of a plant community can be determined by estimating, by harvesting, or by a combination of estimating and harvesting (double sampling) depending on the intended use of the data.

Some plants are on State lists of threatened or endangered species, or are otherwise protected species. Regulations concerning these species may conflict with the harvesting procedures described. For example, barrel-type cactus in some States is a protected species, and harvesting is not allowed.

The weight of such plants is to be estimated unless special permission for harvesting can be obtained. Examiners determining production should be aware of such plant lists and regulations.

When estimating or harvesting plants, include all parts of all plants within the plot, and exclude all portions outside the plot, even though the plants are rooted within the plot. Include portions of plants extending into the plot, but rooted outside the plot (Figure 4).

Exclude
all parts of
all plants
outside the plot

Include
all parts of
all plants
within the plot

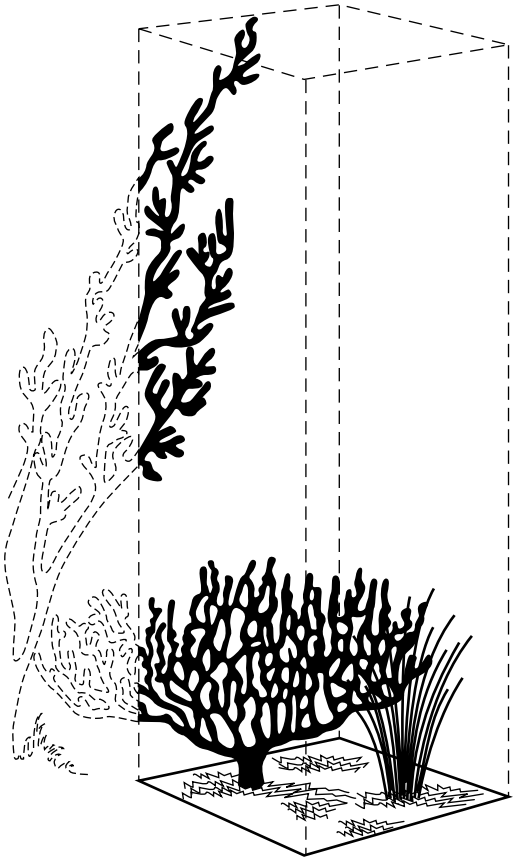


Figure 4 - Weight Estimate Plots. (Adapted from Sampling Vegetation Attributes, Technical Reference 1734-4, Illustration 23, 1996.)

Estimating by Weight Units

The relationship of weight to volume is not constant; therefore, production and composition determinations are based on weight estimates, not on comparison of relative volumes. The weight unit method is an efficient means of estimating production and lends itself readily to self-training. This method is based on the following:

- A weight unit is established for each plant species occurring on the area being examined.
- A weight unit can consist of part of a plant, an entire plant, or a group of plants (see Appendix 6, Examples of Weight Units).
- The size and weight of a unit vary according to the kind of plant. For example, a unit of 5 to 10 grams is suitable for small grass or forb species. Weight units for large plants may be several pounds or kilograms.
- If a majority of estimates for a particular species are in fractions of a weight unit (e.g., 0.1, 0.5, 0.7), then the size of the weight unit is probably too high.
- Other considerations include:
  - Length, width, thickness, and number of stems and leaves
  - Ratio of leaves to stems
  - Growth form and relative compactness of species

The following procedure can be used to establish a weight unit for a species:

1. Decide on a weight unit (in pounds or grams) that is appropriate for the species.
2. Visually select part of a plant, an entire plant, or a group of plants that will most likely equal this weight.
3. Harvest and weigh the plant material to determine actual weight.
4. Repeat this process until the desired weight unit can be estimated with reasonable accuracy.
5. Maintain proficiency in estimating by periodically harvesting and weighing to check estimates of production.

The procedure for estimating production and composition of a single plot is:

1. Estimate species composition by visually estimating the percent by weight of each species with the total weight for the entire plot.
2. Estimate production by counting the weight units of each species in the plot.
3. Convert weight units for each species to grams or pounds.
4. Harvest and weigh each species to check estimates of production.
5. Compute composition on the basis of actual weights to check composition estimates.
6. Repeat the process until proficiency in estimating is attained.
7. Periodically repeat the process to maintain proficiency in estimating.

8. Keep the harvested materials, when necessary, for air-drying and weighing to convert from field (green) weight to air-dry weight (ADW).

Double Sampling—Estimating and Harvesting

The double-sampling method is to be used in making most production and similarity index determinations. The procedure is:

1. Select a study area consisting of one soil taxonomic unit. This should be a soil taxonomic unit that is an important component of a rangeland ecological site or forestland ecological site.

2. Select plots at specified intervals along a linear transect. The starting point is randomly located within the site write-up area (SWA).

3. After plots are selected, estimate and record the weight of each species in each plot using the weight-unit method. When estimating or harvesting, include all parts of all plants within the plot. Exclude all portions of all plants outside the vertical projection of the plot.

4. After weights have been estimated on all plots, select the plots to be harvested. The plots selected should include all or most of the species in the estimated plots. If an important species occurs on some of the estimated plots, but not on the harvested plots, it can be clipped individually on one or more plots. The number of plots harvested depends on the number estimated. To adequately correct the estimates, research indicates at least one plot should be harvested for each seven estimated. At least 2 plots are to be harvested if 10 are estimated, and 3 are to be harvested if 20 are estimated. Table 5 shows the minimum number of plots to be harvested based on the number of estimated plots.

Table 5 - Number of Harvested Plots

Number of Plots Estimated	Minimum Number of Harvested Plots
1 - 7	1
8 - 14	2
15 - 21	3
22 - 28	4
29 - 35	5
36 - 42	6

5. Harvest, weigh, and record the weight of each species in the plots selected for harvesting. Harvest all parts of all plants within the plot. Exclude all portions of all plants outside the vertical projection of the plot.

   Correct estimated weights by calculating an adjustment factor. To do this, divide the harvested weight of each species by the estimated weight for the corresponding species on the harvested plots. This factor is used to correct the estimates for that species in each plot. A factor of more than 1.0 indicates the estimate is too low. A factor lower than 1.0 indicates the estimate is too high.

6. After plots are estimated and harvested and adjustment factors for estimates computed, air-dry percentages are determined by air-drying the harvested materials or by selecting

the appropriate factor from an air-dry percentage table (Appendix 7). Values for each species are then corrected to air-dry pounds per acre or kilograms per hectare for all plots. Average weight and percentage composition can then be computed for the sample area.

Plot Size

Adapt the size and shape of plots to the kind of plants to be sampled. The area of a plot can be expressed in square feet, inches and meters, or in acres.

If vegetation is relatively short, the following plot sizes work best in determining production:

0.96 ft^2 or 41.7 inch circumference
1.92 ft^2 or 59 inch circumference
2.40 ft^2 or 66 inch circumference
4.80 ft^2 or 93.2 inch circumference
9.60 ft^2 or 131.8 inch circumference

The listed plots are the most useful when converting grams to pounds per acre. The 9.6 ft^2 plot is generally used in areas where vegetation density and production are relatively light. The smaller plots, especially the 0.96 ft^2 and 1.92 ft^2 plots, are satisfactory in areas of homogeneous, relatively dense vegetation like that occurring in meadows. Plots larger than 9.6 ft^2 should be used where vegetation is very sparse and heterogeneous.

If the vegetation consists of trees or large shrubs, larger plots must be used. If the tree or shrub population is uniform, a 0.01 acre plot is more suitable. If vegetation is unevenly spaced, a more accurate sample can be obtained by using a 0.1 acre plot, 4.356 feet wide and 1,000 feet long. For statistical analyses, 10 plots of 0.01 acre are superior to a single 0.1 acre plot. Plots of 0.1 and 0.01 acre are most useful when production data is collected in pounds because it is a direct conversion.

If vegetation is mixed, two sizes of plots generally are needed. A series of 10 square or rectangular plots of 0.01 acre and a smaller plot, such as the 9.6-square-foot plot nested in a designated corner of each larger plot, is suitable. The 0.01-acre plot is used for trees or large shrubs, and the smaller plot for lower-growing plants. Weights of the vegetation from both plots are then converted to pounds per acre. Plots with area expressed in square meters are used if production is to be determined in kilograms per hectare.

If the plots are nested, production from both plots must be recorded in the same units of measure. For example, a plot 20 meters by 20 meters (or other dimensions that equal 400 meters) can be used for measuring the tree and shrub vegetation and a 1-meter plot nested in a designated corner can be used for measuring the low-growing plants. Determine the production from both in grams and convert the grams to kilograms per hectare. Plots of 0.25, 1, 10, 100, and 400 square meters are commonly used.

Plot Shape

Plots can be circular, square, or rectangular. However, long-narrow plots are likely to be more accurate than circular, square, or rectangular plots (Krebs 1989). Edge effect can result in significant measurement bias if the plots are too small (Wiegert 1962). Since aboveground vegetation must be clipped in some plots, circular plots should be avoided because of the difficulty in cutting around the perimeter of the circle with hand shears and the likely measurement bias that would result.

Harvesting

This method is similar to the double-sampling method except that all plants in all plots are harvested. The double-sampling procedures for estimating weight by species and the subsequent correction of estimates do not apply. Conversion of harvested weight to air-dry pounds per acre or kilograms per hectare are performed according to the procedures described for double sampling.

Units of Production and Conversion Factors

All production data are to be expressed as ADW in pounds per acre (lb/acre) or in kilograms per hectare (kg/ha). The field weight must be converted to ADW. This may require drying or the use of locally developed conversion tables.

Plot Size Conversion Factors

All weights need to be converted to pounds per acre. The following plot size conversion factors (CFs) calculate pound per acre or kilograms per hectare for various weight units (e.g., grams or pounds) and plot sizes (e.g., 9.6 ft^2, 0.1 acre, 1 m^2, 400 m^2).

The weight of vegetation on plots measured in square feet or in acres can be estimated and harvested in grams or in pounds, but weight is generally expressed in grams. If weights are collected on 10 plots, the total weight is converted to pounds per acre by using the factor in column 3. If production is collected on less (or more) then 10 plots, divide the total for the entire transect by the number of plots and use the conversion factor in column 4.

To convert grams to pounds per acre, use the conversions in Table 6.

Table 6 - Conversion Factors for Grams to Pounds per Acre

Plot Size	Weight Unit	Conversion Factor Per 10 Plots	Conversion Factor Per Plot
0.96 ft^2	grams	10	100
1.92 ft^2	grams	5	50
2.4 ft^2	grams	4	40
4.8 ft^2	grams	2	20
9.6 ft^2	grams	1	10
96. ft^2	grams	0.1	1
.01 acre	grams	10	100
.1 acre	grams	1	10

In the metric system, a square-meter plot (or multiple thereof) is used. Weight on these plots is estimated or harvested in grams and converted to kilograms per hectare. A hectare equals 10,000 square meters. A kilogram equals 1,000 grams. If weights are collected on 10 plots, the total weight is converted to kilograms per hectare by using the factor in column 3. If production is collected on less (or more) then 10 plots, divide the total for the entire transect by the number of plots and use the conversion factor in column 4.

To convert grams per plot to kilograms per hectare, use the conversions in Table 7.

Table 7 - Conversion Factors for Grams to Kilograms per Hectare

Plot Size	Weight Unit	Conversion Factor Per 10 Plots	Conversion Factor Per Plot
0.25 m^2	grams	10	100
1 m^2	grams	10	100
10 m^2	grams	10	100
100 m^2	grams	10	100
400 m^2	grams	10	100

Mixed Measuring Units

With large volumes of vegetative material associated with trees and large shrubs, it is more practical to estimate weights in pounds rather than grams. The conversion factor on a *per plot* basis, when weights are collected in pounds for a 96 ft^2 plot, is 454. Likewise, vegetative material associated with grasses, forbs, and small shrubs is more easily estimated in grams. Therefore, on a per plot basis, weights collected in grams for a .1 acre plot would convert to 2.2 pounds per acre (conversion for a 0.01 acre plot is 0.22).

Adjustment Factors

The ideal situation for determining production data for each individual species is to sample them when they are at their maximum production. With a diversity of species, it is impossible to make these determinations at one point in time during the growing season. Therefore, the production of each species must be reconstructed to reflect total annual production. This is accomplished using the conversion factors described previously.

Green Weight Adjustment Factor

This is the procedure for converting green weight, which is the weight of vegetation estimated or collected in the field, to air-dry weight.

ADW percentages for various types of plants at different stages of growth are provided in Appendix 7. These percentages are based on currently available data and are intended for interim use. As additional data from field evaluations become available, these figures will be revised. ADW percentages listed in Appendix 7 can be used for other species having growth characteristics similar to those of the species listed.

States that have prepared their own tables of air-dry percentages on the basis of actual field experience can substitute them for the tables in Appendix 7. Be sure to check with the local office of the NRCS for their latest ADW percentage tables. It is recommended that local field offices develop these tables for local conditions and species. Some interpolation must be done in the field to determine air-dry percentages for growth stages other than those listed. If ADW percentage figures have not been previously determined and included in ADW percentage tables, or if ADW conversion factors need to be checked, retain and dry enough harvested material samples to determine ADW percentages.

The relationship of green weight to ADW varies according to such factors as exposure, amount of shading, time since last rain, and unseasonable dry periods. Several samples of plant material should be harvested and air-dried each season to verify the factors shown in Appendix 7 or to establish factors for local use.

Double Sampling Adjustment Factor

This is the adjustment factor calculated from the double sampling process (see Double Sampling—Estimating and Havesting, number 6). The harvested weights are divided by the estimated weights. A factor of more than 1.0 indicates the estimate is too low. A factor lower than 1.0 indicates the estimate is too high.

Air-dry Weight Adjustment Factor

This is the appropriate ADW percent in decimals from tables and charts that convert green weight to ADW based upon various stages of growth.

Utilization Adjustment Factor

This is the percent of the plant's **current growth** remaining at the time of sampling. Biomass lost as a result of herbivory (e.g., livestock, wildlife, insects) must be recognized and re-created in order to provide a more accurate estimate of the total current year's annual production for individual species and the plant community. The utilization adjustment attempts to restore this missing amount of production. The examiner determines the percent of the current year's growth that remains. This is actually the reverse of percent utilized. For example, if utilization on a plant species averages 30 percent on the production transect, the percentage of the plants remaining would be 70 percent. Thus, the adjustment entered for that particular species would be 0.70. Utilization may vary throughout the weight estimate plots, requiring an estimate of the average use to determine the adjustment.

Growth Adjustment Factor

This is the percent of growth (in decimal form) that has occurred up to the time plot data is collected. The values entered can reflect the growth curves for the site (as listed in some site descriptions), or it could be based upon locally developed growth curve data for each species.

Reconstructing the Present Plant Community

The existing plant community at the time of inventory must be reconstructed to the normal annual air-dry production before it can be compared with the reference plant community. The reconstruction must consider physical, physiological, and climatological factors that affect the amount of biomass measured (i.e., weighed or estimated) for a species at a specific point in time. The present plant community is reconstructed by multiplying the measured weight of each species by a reconstruction factor. The reconstruction factor formula is:

$$\text{Reconstructed} \quad \frac{(GW)\,(A)\,(B)\,(C)}{(D)\,(E)}$$

where:

GW = Green weight
A = Plot size conversion factor
B = Double sampling adjustment factor, if appropriate
C = Percent of air-dry weight (ADW)
D = Percent of plant biomass of each species that has not been removed
E = Percent of growth of each species that has occurred for the current growing season

Ocular Estimation of Production Data

Ocular estimates of production for an entire site, as opposed to estimating production on individual plots, is the quickest and easiest technique. However, with inexperienced people, the reduced accuracy resulting from this technique limits the use of the data. Ocular estimates are useful in quickly determining the similarity index of a site (see Chapter 5) for use in mapping plant communities and in stratifying SWAs for sampling purposes.

The following procedure is used in to become proficient at estimating production for an SWA.

1. Estimate production, in pounds per acre or kilograms per hectare, of individual species on the site.

2. Estimate production of individual species on a series of random plots.

3. Compute production in pounds per acre or kilograms per hectare from the random plots. To further check these estimates, harvest or double sample according to procedures addressed in the double sampling section of this document.

4. Repeat procedure until proficiency is attained.

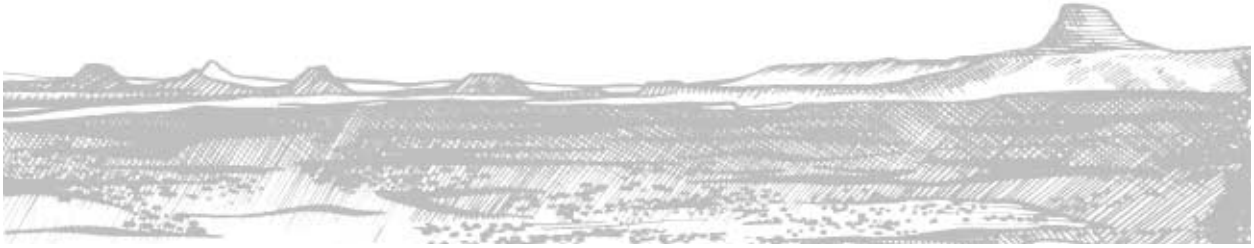
Although this procedure misses some species of minor importance, it provides a useful check on estimates.

Inventory Level of Intensity

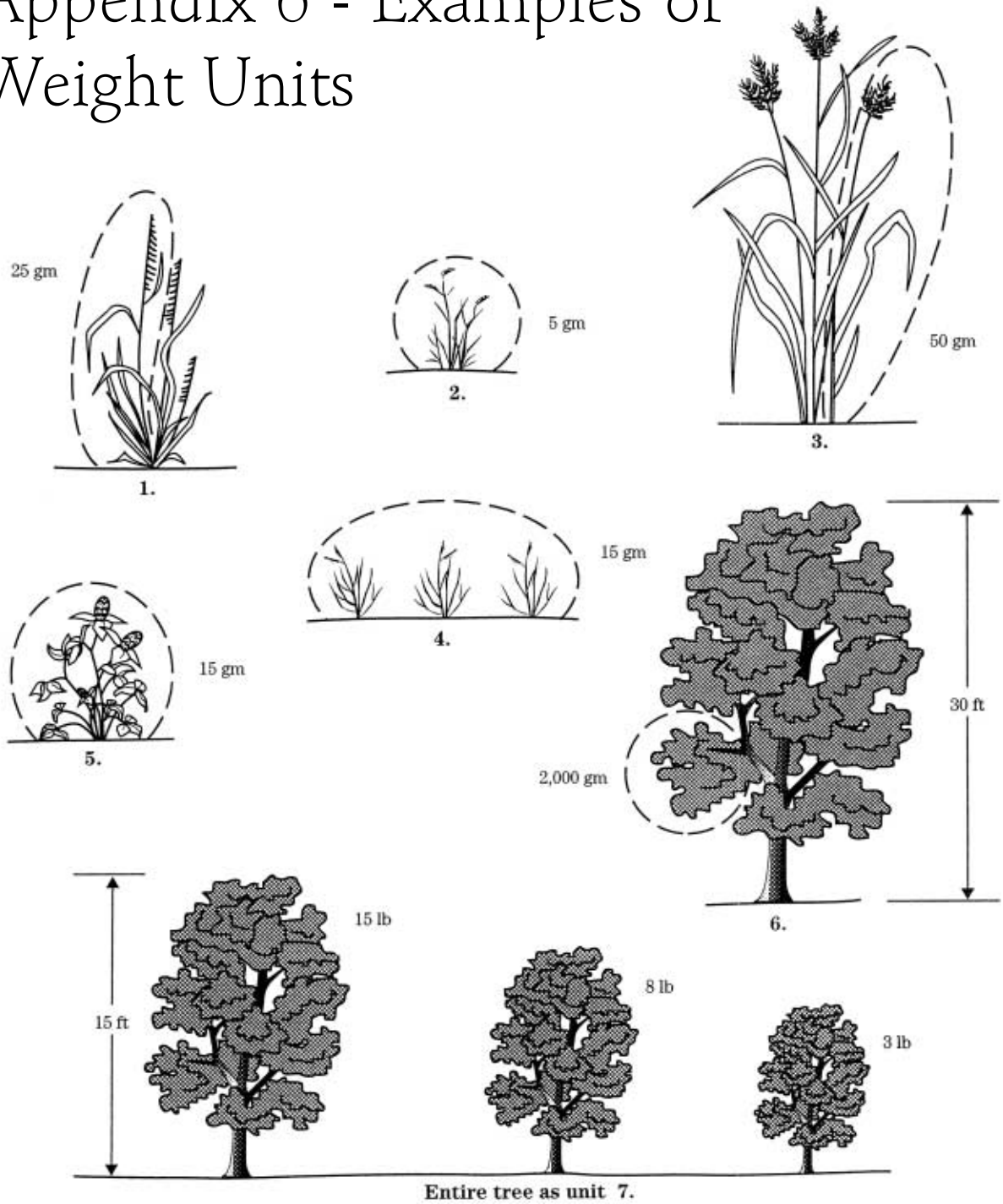
The minimum standard for an ecological site inventory is production by species. The level or intensity at which the production of a plant community is determined depends on the intended use of the data. Ocular estimates are the quickest and easiest technique for determining production, but may result in reduced accuracy, limiting use of the data. Estimating production of individual species on production plots is more time consuming, but the accuracy of the data is significantly increased, especially if plots are periodically harvested and weight-unit weights are adjusted accordingly. Harvesting is the most accurate technique, but because of the additional time required for collection is seldom used except in research-type efforts. A combination of harvesting and estimating or double sampling is probably the best technique for documenting the production on the site. Double sampling is the technique NRCS uses for documenting new ecological site descriptions and revising existing descriptions. Even with the estimating technique, frequent clipping studies (harvesting) should be conducted to calibrate the observer's eye.

Production Data for Documenting Rangeland Ecological Sites

Data to be used for preparing rangeland ecological site descriptions and grouping soils into rangeland ecological sites are to be obtained by the double-sampling procedure. All documented production and composition data are to be recorded on the Vegetation Production Worksheet in Appendix 4. Specific procedures for documenting an ecological site description can be found in the NRSC National Range and Pasture Handbook, Chapter 4.



Appendix 6 - Examples of Weight Units



(Reprinted from 190-vi, NRPH, September 1977)

Appendix 7 - Percentage Air-dry Weight Conversion Table

Percentage of Air-dry Weight in Harvested Plant Material at Various Stages of Growth

Grasses	Before heading initial growth to boot stage (%)	Headed out: boot stage to flowering (%)	Seed ripe: leaf tips drying (%)	Leaves dry stems partly dry (%)	Apparent dormancy (%)
Cool season wheatgrasses perennial bromes bluegrasses prairie junegrass	35	45	60	85	95
Warm season Tall grasses bluestems indiangrass switchgrass	30	45	60	85	95
Midgrasses side-oats grama tabosa galleta	40	55	65	90	95
Short grasses blue grama buffalograss short three-awns	45	60	80	90	95
Trees	New leaf and twig growth until leaves are full size (%)	Older and full size green leaves (%)	Green fruit (%)	Dry fruit (%)	
Evergreen conifers ponderosa pine, slash pine-longleaf pine Utah juniper rocky mountain juniper spruce	45	55	35	85	
Live oak	40	55	40	85	
Deciduous blackjack oak post oak hickory	40	50	35	85	

USDA, National Resources Conservation Service, National Range and Pasture Handbook

Percentage of air dry matter (continued)

Shrubs	New leaf and twig growth until leaves are full size (%)	Older and full-size green leaves (%)	Green fruit (%)	Green fruit (%)
Evergreen big sagebrush bitterbrush ephedra algerita gallberry	55	65	35	85
Deciduous snowberry rabbitbrush snakeweed Gambel oak mesquite	35	50	30	85
Yucca and yuccca like plants yucca sotol saw-palmetto	55	65	35	85

Forbs	Initial growth to flowering (%)	Flowering to seed maturity (%)	Seed ripe leaf tips dry (%)	Leaves dry stems drying (%)	Dry (%)
Succulent violet waterleaf buttercup bluebells onion, lilies	15	35	60	90	100
Leafy Lupine lespedeza compassplant balsamroot tickclover	20	40	60	90	100
Fibrous leaves or mat phlox, mat eriogonum pussytoes	30	50	75	90	100

Succulents	New growth pads and fruit (%)	Older pads (%)	Old growth in dry years (%)
Prickly pear and barrel cactus	10	10	15+
Cholla cactus	20	25	30+