Measurement of Herbaceous Aboveground Phytomass
Exercise 5

As plants grow and develop throughout the year they progress through a series of stages that affect the size of the plant, leaf and root mass, reproductive structures, and the amount of nutrient available for the plant's sustenance and survival. These "Phenological Stages" also affect the chemical nature of the plant and the amount and type of carbohydrate, protein, lipid that is distributed throughout the plant body. Phenological stages and plant growth are largely controlled by weather conditions and each environment across the globe varies slightly. As a natural consequence of nature of tropic hierarchies, herbivores must cope with underlying changes in vegetative food supplies as they advance and decline with seasons.

In our Mediterranean climate, plant growth generally begins in the fall with the onset of rain after the dry summer. Below is the weight of five orchardgrass (*Dactylis glomerata* L.) plants growing in the area (Table 1). We estimated aboveground weight by clipping at ground level, and weighing a series of very similar plants growing on the same site. The five orchardgrass plants that were the experimental subjects were then compared to the clipped plants and the green weight was estimated, thus sample/ "test" plants remained intact. Green weight was converted to oven dry weight (Dry Matter) by clipping 10 orchardgrass plants, weighing green, oven drying at 55°C until the weight stabilized, then reweighing. Mean green weights of test plants was then multiplied by the wet/dry conversion factor for that sampling date (mean oven dry proportion of the 10 plants) to obtain an estimate of oven dry weight of above-ground green material for each experimental plant.

Orchardgrass is an important perennial, cool-season, bunch grass that is very palatable to both wildlife and domestic livestock. It is widely used in pastures and on rangelands throughout the Mediterranean climatic zone worldwide. Although it is an introduced plant in many regions, it has become naturalized in all 50 states and most of Canada where it is adapted to the better well-drained soils. Orchardgrass is often seeded in mixtures with legumes such as alfalfa or red clover where it provides high quality forage and hay.

Table 1. Growth of Orchardgrass (*Dactylis glomerata* L.) on a site in Jackson County, Oregon during the 2000 forage year.

Date	Orchardgrass Above-Ground Green Phytomass (Dry Matter in Grams)				
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
December 11, 2000	2.7	3.2	3.1	2.4	2.6
January 2, 2001	3.9	4.1	5.0	3.5	4.0
March 12, 2001	5.6	5.6	6.6	5.2	5.6
April 15, 2001	7.6	7.1	9.3	6.2	7.6
May 24, 2001	27.9	22.6	26.0	19.4	28.3
June 7, 2001	34.3	32.2	37.6	30.4	35.2
June 28, 2001	43.1	40.6	48.2	39.2	44.6
July 5, 2001	7.2	2.3	4.4	5.4	3.0

When range managers or scientists measure plant or forage growth, they usually measured periodically throughout the growing season to resolve the "forage calendar" or the amount of forage available to livestock or wildlife in each month or fortnight of the year on a landscape. If production is measured only once, they try to obtain an accurate estimate of “peak standing crop” or the maximum amount of green phytomass on the ground. In our orchardgrass example, peak standing crop occurred around the 28th of June.

Plant growth in our area generally commences with “breaking rains” which come in the fall. They are called breaking rains because under our Mediterranean Climatic regime summers are typically hot and dry and winters are cool and wet. If breaking rains come early in the fall when temperatures are still warm, grass re-grows and life is good for herbivores, however if they come late, little or no regrowth occurs before temperatures are to low enough to allow growth. The late rain scenario therefore can cause hardship for animals going into winter conditions.

The orchardgrass growth data documents a 10 fold increase in the above-ground green material between December and July and that phytomass production was dynamic. Good managers have a good understanding of plant growth dynamics and its impact on animals and ecosystem health.

In this exercise we will learn how to estimate above-ground phytomass using the clip and weigh process. Rather than estimate the weight of a single plant of a single species as I did above, we will estimate the weight of all green plant material growing on a small, well-defined surface area of land. Because measuring plant biomass task becomes more difficult as the size of the area sampled becomes larger, managers and scientists generally limit the sample (quadrat) to between 0.1 m^2 and 1 m^2. We will define the sample area by using a metal or plastic frame, called a “quadrat” or “hoop” of a fixed size.

Because dead plant material on the surface protects the soil from the impact of raindrops and represents organic matter that will hopefully be incorporated into the soil in the future, it is also of ecological/agronomic importance and we will also estimate the mass of litter in the quadrat, as either current year's or past year's material.

People that raise livestock for a living realize that forage yield measurements are extremely important for valuing pasturage that is leased or sold as well as managing and planning livestock feeding operations across seasons and years. Knowledge of the “forage calendar” and its year-to-year fluctuation allows them to set reasonable stocking rates and calculate in advance the need for hay and concentrate feeds. Hay is usually much more expensive than pasturage because of harvest and transport costs. A manager’s knowledge of the forage calendar and experience with vagaries of weather in a region often separates failed ranching and livestock operations from successful ones. In a similar fashion, wildlife managers also use plant production information for calculating carrying capacities and to determine of critical habitats for herbivores. Whether you are managing domestic stock or wildlife, you must know how to measure plant yield.

Equipment Needed

We often sample in teams of 2 people; one to read the plot and one to record data. Each team will require:

1. Grass shears or Clippers
2. Paper bags

3. Permanent Marker
4. Quadrat or hoop of known area
5. Scale or balance (see http://www.americanweigh.com/)
6. Clipboard or Notebook

Figure 1. A circular metal quadrat that can be used to sample herbaceous vegetation on rangelands. Quadrats may be of various shapes and sizes. The most common sizes are 0.10m^2, 0.25m^2, 0.5m^2 and 1.0m^2. Quadrats can be round, square, or rectangular.

Procedure

We will first identify the boundary of the pasture or system we are measuring. In pastures that are uniform this is usually the fenced area but on open extensive landscapes the sampled areas frequently represent range sites, ecological sites, or vegetation types. The reason we sample by range or ecological site is that the efficiency of sampling increases if we stratify land by productive potential. We typically want to sample within uniform areas so the internal variation in production from observation to observation is lessened. In the example below, we have high-producing wet meadows interspersed with low-producing rocky hummocks with shallow soils. A few samples can be taken on wet meadows to get a pretty good estimate of production with fair degree of confidence. Likewise, a few samples can be taken on the shallow rocky uplands to get a good estimate of production with good reliability. If, however, we sample both together we obtain a mean production value with extreme internal variation and have little confidence in the estimate (Table 2).

Table 2. Measurement of above-ground plant production on two widely different sites separately and together. Note that the standard deviation, a measurement of variability or dispersion of data points from the average, is much higher when sites are measured together. A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data is spread out over a large range of values.

Observation	Wet Meadow (kgDM/ha)	Shallow Rocky (kgDM/ha)	Wet Meadow + Shallow Rocky (kgDM/ha)
1	**1875**	**375**	**1875**
2	**1930**	**413**	**375**
3	**1910**	**394**	**1930**
4	**2015**	**417**	**413**
5	**1850**	**388**	**1910**
Mean	**1916**	**397**	**1301**
Standard Deviation	**63**	**18**	**828**

Randomness

If we want to draw inferences from the information we are collecting using statistical procedures, we need to introduce randomness into the sampling process. Randomness means that each sample is selected so that all samples (plots of the same size) from the population have an equal chance of being selected. Thus, we are not skewing or biasing the observations or collected data. Bias can either very subtle or blatant. If we were sampling in the summer during mosquito season, we might be tempted to avoid the wet areas in favor of the more breezy mosquito-free open lands when placing our quadrats on the ground. This would obviously bias our sample and lead to a lower estimate of yield for the pasture. The way to avoid this problem is to map the pasture, stratify it according to vegetation type, randomly choose sample locations within each type, and then allocate sampling effort until each type is sampled adequately. I have provided you with 3,000 random digits in a table at the end of this laboratory exercise. We will discuss the proper use of the random number table in class.

Random sample locations are often determined by gridding the pasture being measured then selecting the row and column where the quadrat will be lain using a random number generator or a random number table. As shown in Table 3, you would have a series of coordinates that would represent locations to be sampled.

Table 3. Seven randomly positioned locations in a gridded pasture.

Sample	Column	Row
1	21	2
2	16	0
3	26	20
4	1	10
5	10	17
6	13	11
7	4	7

An example of the gridded OSU Witham Hill Pasture is given in Figure 1.

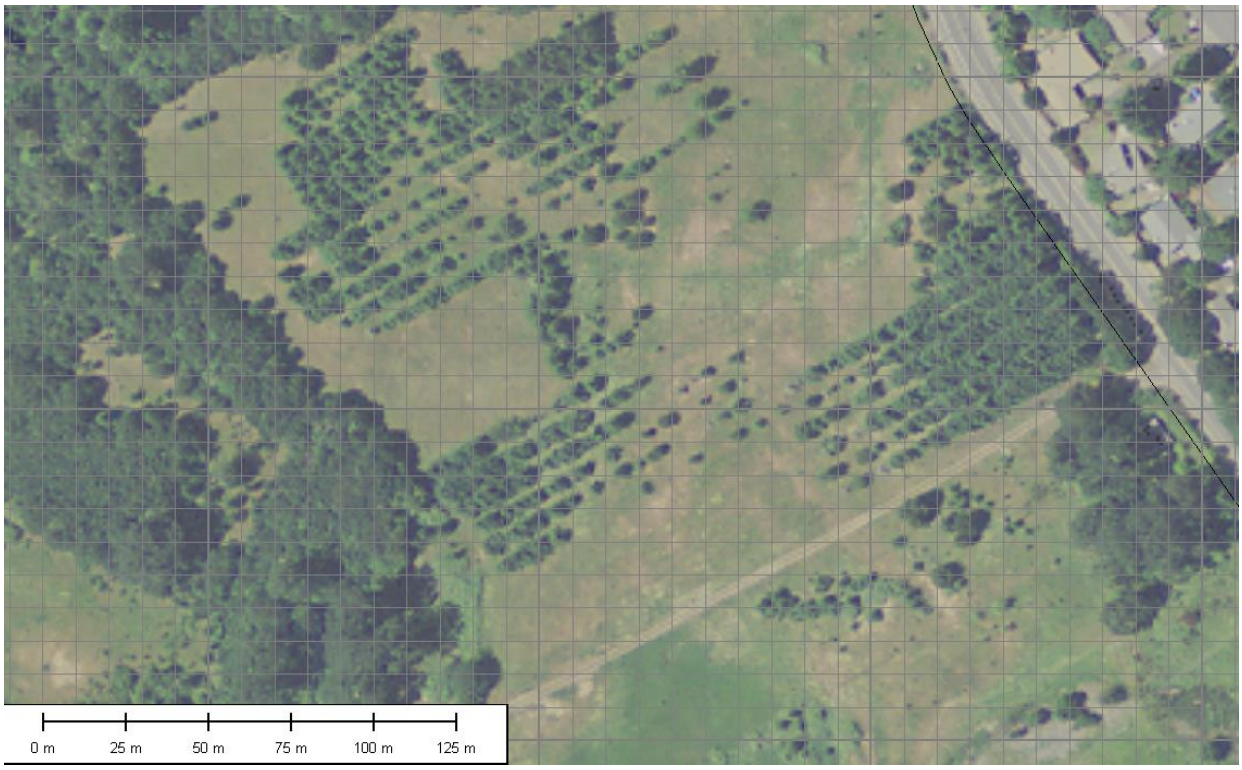

Figure 2. A portion of the Oregon State University College Pasture on Witham Hill gridded with lines 10 meters apart.

As you can imagine, the process of gridding the area to be sampled, then moving from random point to random point is time consuming, tedious, and not often done. Usually a modified process is used, especially when data is being collected for routine managerial decision making and not for scientific study. With this process, you begin at a random starting location in a vegetation type, and then proceed a random number of paces in a random direction to get to the sample point. Subsequent sample points are found by a going in a random direction and a random distance from the previous point until the vegetation type is adequately sampled. This is not truly random sampling but it at least approximates randomness. In agronomic field plot experimentation and for scientific research, you should use random samples.

In this exercise, each sampling team or individual will clip 15 plots, located by the random start-random direction- random distance method. You will lay a plot frame on the ground and clip all the plant material inside the frame at ground level. Before the plot is clipped, you should also estimate the weight of green vegetation in the quadrat and write it on the data sheet. To help you out, remember a nickel weighs 5 grams. Clipped material should be separated into green, current year's litter and old litter placed in separate paper bags, weighed using a portable postage scale, and labeled. Remember the paper bag has weight and you must account for it when weighing forage. We do this by weighing the empty bag then adding materials and weighing the combination. The "tare" of a bag or container is its weight when it's empty, which is then subtracted from the combined weight. Be sure to record your data on the data forms provided.

You should also save the 1st, 5th, 10th, and 15th bags of forage that you clip for determination of dry matter. We will dry them in an oven to determine their wet to dry conversions. Because water is easily and cheaply obtained and does not contribute dietary energy to the animal most feeds are evaluated on a moisture-free basis. Thus, we should be specific as to what is being measured and reported for our range forage or aboveground phytomass.

Usually, the composition of forage is reported on one of the following forms:

1. As-Fed feed as it is normally fed to animals with moisture included.
2. Air-Dry feed that is dried by means of natural air movement (≈90% dry matter)
3. Moisture-Free Feed has been oven dried at 105°C until all moisture has been removed

For this exercise, we will oven dry the samples to obtain the Moisture-Free weight. We multiply field sample weights by their proportion dry matter to convert them to a moisture free weight basis. Please calculate the percent dry matter using the formula:

$$\% \text{ DM} = (\text{dry weight}/\text{wet weight}) \cdot 100$$

Calculations

Please calculate the following:

a) Tare of the bag in grams (both wet and dry)
b) Wet weight of forage, current year's litter, and old litter in g/m^2, and kg/ha
c) Percent dry matter (DM) of clipped forage, current year's litter, and old litter (Wet weight/Dry Weight Conversions)
d) Mean, standard deviation, and standard error of the forage dry weight, current year's litter weight (DM), and old litter weight in gDM/m^2 and kgDM/ha.

Questions

1. One of the calculations managers frequently make is the allowable duration of grazing in a pasture. If we know how much forage is available and how much the flock or herd eats on a daily basis, we can calculate how many days the flock can be in the pasture. Our pasture is normally grazed by sheep. If the pasture is 10 ha, you have 50 ewes, and a ewe in late gestation eats about 1.9 kg of Dry Matter/day, how long could you graze your flock given your estimate of forage? Assume that sheep will actually only eats about 1/2 of the forage available in the pasture.
2. This pasture is a mixture of many plant species, some herbaceous and some not, some palatable and some not. If you wanted a better estimate of available forage and wanted to base it on what was actually eaten by the sheep, how could you determine diets? By this I mean separate consumable plant material from material not consumed by sheep.

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Above-ground Herbaceous Biomass Data Form

Name: _____
Date: _____
Location: _____ Long._____ Lat. _____
Quadrat Size: _____
Bag Weight (Wet) _____
Bag Weight (Dry) _____

Sample	Estimated Weight + Bag (g)			Clipped Weight + Bag (g)			Net Oven Dry Matter (g)		
	Green	Current Litter	Old Litter	Green	Current Litter	Old Litter	Green	Current Litter	Old Litter
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
Mean									
Standard Deviation									

Notes: _____

_____

_____

_____

_____

_____

300 Random Numbers between 0 and 1000

284	432	727	953	294	71	414	869	154	721
860	461	87	584	677	14	349	765	593	732
10	175	663	585	134	775	914	37	408	766
884	12	900	50	472	64	492	519	862	654
901	132	867	745	851	818	273	564	543	725
561	321	494	1	57	698	884	237	537	852
341	506	766	162	424	209	785	352	524	47
700	318	954	705	360	645	818	873	230	697
669	559	517	16	427	598	953	136	912	768
237	507	948	390	342	493	211	172	197	182
532	429	70	270	727	321	627	700	976	558
942	434	35	580	107	604	390	151	931	445
666	344	470	692	847	407	435	473	155	460
135	649	395	127	484	474	133	840	405	129
70	938	788	175	932	786	578	869	776	36
908	94	30	404	78	146	428	100	903	135
385	948	959	751	708	103	977	599	596	187
615	68	646	949	138	305	108	876	697	248
876	697	212	974	504	362	89	831	473	550
128	922	795	962	726	681	765	957	942	772
623	437	843	869	18	447	78	329	657	227
320	457	292	906	718	185	277	106	451	705
0	666	691	860	465	787	61	765	558	9
611	888	978	16	224	918	376	264	962	696
739	769	148	683	31	674	512	61	31	496
621	821	26	259	633	166	140	446	405	659
221	412	713	575	43	215	538	661	140	742
942	442	817	183	867	818	193	553	569	145
623	513	958	639	649	69	461	845	976	222
544	831	76	956	657	329	137	455	92	532

Useful Terms

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

Browse - The portion or amount of woody plants available for animal consumption. It is generally measured as the current season's growth of twigs and leaves.

Forage - Herbage and browse which is potential food for animals.

Gross Primary Production - The total amount of energy or organic matter produced in an ecosystem including above ground (leaves and stems) and below ground (roots) biomass in a given year.

Herbage - Above-ground biomass of herbaceous plants.

Peak Standing Crop – greatest amount of standing plant mass observed during a given year.

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

Standing Crop - amount of green biomass on the ground at a point in time.