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Developing Temporal Biomass Production Curves (Growth Curves) for Annual and Perennial Grass Species for Ecological Site Descriptions

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Introduction

Growth curve data and graphical representations are important in showing growth of plants over time (fig. 1a). Growth curve data used in ecological site descriptions represent average values, however, rates of growth of a plant will vary with climatic factors (available water and temperature). Typically, a growth curve is sigmoid in shape and shows a dormant phase, lag phase representing initial startup growth, the log or exponential phase where maximum growth occurs, and a diminishing phase where growth slows and eventually stops. Some plant species exhibit a bimodal growth curve with two or more growth periods (fig.1b).

Figure 1a: Sigmoid Plant Growth Curves

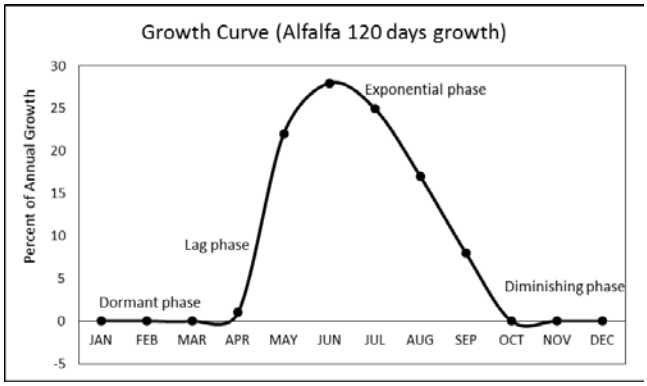
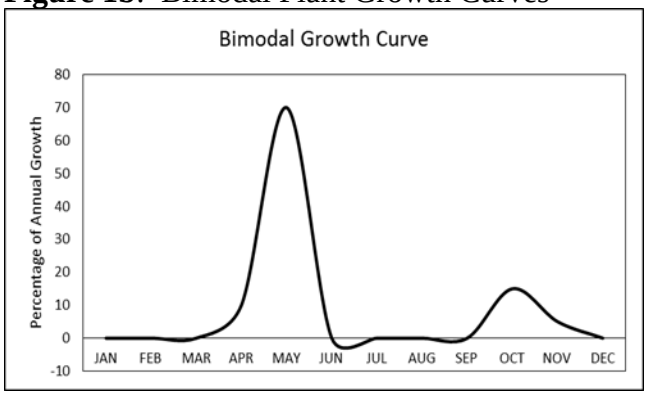


Figure 1b: Bimodal Plant Growth Curves

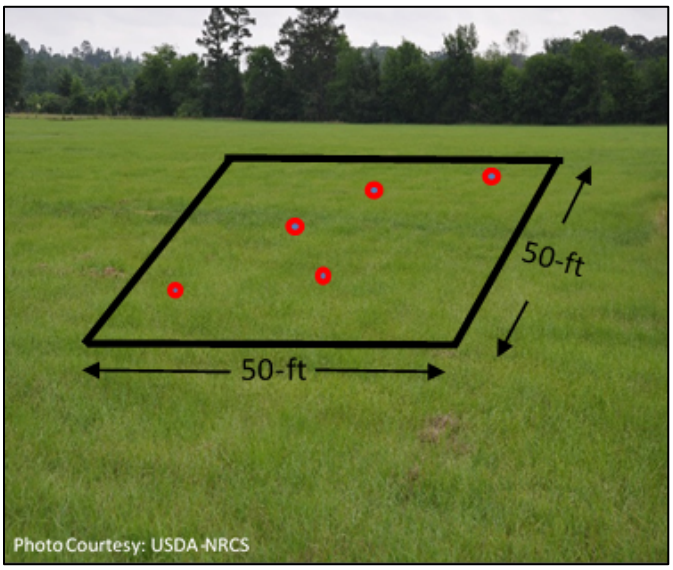


Developing Growth Curve Using Established Grasses

To develop growth curves of annual and perennial grasses requires a well-managed pasture or range site of the desired grass. Contact the local NRCS field office for assistance in identifying a landowner or manager agreeable to providing a site for a minimum of 3 years and willing to manage the grass for sustainable production (e.g., proper grazing management, fertility, mowing, or burning to remove previous year's growth, and irrigation). When selecting a pasture or range site of the target grass, choose an area large enough for multiple clippings during the growing season with planning considerations given to size of the sample clipping frame (1.92 ft^2 and 4.8 ft^2) and uniformity of the

grass stand. Select open areas where the soil type is the same and the topography is relatively level (representative slope and aspect) and protected from livestock and farm traffic. Avoid areas near tree lines and low areas prone to flooding. The size of the sampling area may be larger or smaller than the examples in figures 1a and b. The example of a 50-ft x 50-ft sampling area in figure 2 ensures enough area for multiple monthly clippings, unintentional damage to the sampling area, and use of the growth curve sample (GCS) site location model to identify random sampling points within the sampling area (appendix 2 of this technical note).

Figure 2: Sampling Area With Sample Points (not to scale)



Developing Growth Curve From Newly Established Grasses

If a stand of the target grass is not available, establish a large enough block of the target grass (e.g., 50 ft x 50 ft) following site criteria mentioned above for an existing grass stand. A potential location for these types of plantings is at a plant materials center or similar facility where planting equipment and knowledge of cultural practices for establishment and management of the grass is available or known. Refer to the State's Conservation Practice Standards Forage and Biomass Planting (Code 512) or Range Planting (Code 550), and other associated practices, to achieve a successful stand of the grass and how to manage it for optimum production. A minimum of 1-year establishment period is required for most perennial grasses before initiating the first clipping. In arid regions, where irrigation is not available, establishment period may require a longer time to achieve a suitable grass stand.

Growth Curve Procedure Field Data Spreadsheet (see appendix 3)

The Growth Curve Procedure Field Data Spreadsheet (GC Spreadsheet) is an Excel spreadsheet developed to guide field staff in developing growth curves of annual and perennial grasses for ecological site descriptions. It is an integral part of this technical note and contains four worksheets (Field Information, Required Sample Size, Small and Large Samples). Tabs at the bottom of the spreadsheet identify each of the four worksheets. The "Field Information" worksheet provides the user with a place to record information about the soils, field office, and who and where the samples were collected using global positioning system (GPS). The "Required Sample Size" is a tool to determine the number of samples to collect for sampling integrity. Instructions for using the *n* formula are in the "Required Sample Size" tab next to the *n* formula calculations. The "Small Sample" worksheet allows the user to

enter information about the grass, phenological growth stage at the time of clipping, clipping date, monthly rainfall, and the dry weight of the sample. The user selects the frame size (1.92 ft^2 and 4.8 ft^2) for yield calculation. The user may elect to fill-in the phenological growth stage (see appendix 1 for description of growth stage) or select the growth stage from the pull-down menu. The "Large Sample" worksheet serves the same purpose as the "Small Sample" worksheet except it is for larger samples requiring a subsampling method to make the sample more manageable for drying.

Equipment Needed

- GC Spreadsheet (see "Field Information" tab)
- Growth stage description (appendix 1 of this technical note)
- Measuring tape
- 1.92 ft^2 or 4.8 ft^2 clipping frame (Title 190, National Range and Pasture Handbook (190-NRPH))
- Hand clippers
- Wooden stakes
- Paper sacks (size #20 to 25 (lunch size); or grocery size for larger samples (size #57)
- Weighing scales (0.10 lb increment)
- Weighing tub or tarp for the larger samples
- Small scales (>2000 gram maximum weight; 0.10 gram increments)
- Permanent marker pen
- Drying oven (optional) (60°C minimum temperature)
- A GPS unit is required with the GCS site location model

Harvest Procedure

Choose a frame size (1.92 ft^2 or 4.8 ft^2) most appropriate for the pasture or range condition (190-NRPH). For improved yield accuracy choose the larger frame. Make the first harvest when plants reach the vegetative/leaf development growth stage (see Appendix 1, "Phenological Growth Stage Descriptions").

1. Use one of the following methods to determine sample points in the field:
   a) Use the NRCS ArcGIS GCS location model to identify the sampling unit and to assign five random sampling points within the 50-ft x 50-ft sampling unit. (Instructions provided in appendix 2.)
   b) Identify the sampling units subjectively without preconceived bias. Avoid areas previously clipped during the growing season (see bullet 10 below).
2. For grasses established in 50-ft x 50-ft block assign clipping periods (monthly or based on phenological growth stage of the grass) using the most appropriate method to obtain a random sample (XY coordinate/grid overlay).
3. Complete the "Field Information" worksheet of the GC Spreadsheet and determine what size of sample is most appropriate for the size of the clipping (see sections "Small Sample" or "Large Sample" on next page of this document).
   a) Record the height of the grass on the sample worksheet. Measure from ground level to the highest point (absolute height) of the plant. Do not extend the vegetation to measure height.
   b) Record the phenological growth stage of the grass using the description in the "Growth Curve for ESD" tab (explanation of growth stages) and use the drop-down menu on the worksheet to choose the growth stage.
4. Facing north, position the sampling frame over the area to sample working it down until it lies flat on the soil surface.

5. Sample the grass rooted in the sampling frame, do not include overhanging nonrooted plants. If the frame splits a clump of grass or crown, separate the biomass material so that only the material that comes from the portion of the clump or crown inside the frame is included.
6. Estimate the line that closes the end of the open sampling frame and separate above-ground material along that line by bending back that portion of the grass that would be outside the frame.
7. Clip biomass within the sampling frame to a stubble height of at least 1 inch or less.
   Note: Elevated crowns of some perennial grasses may hinder cutting to 1 inch. In such cases, cut the biomass as close to a 1-inch-stubble height as possible. Remember you are determining total biomass and that requires cutting the plant as close to the soil surface as possible.
8. Place the biomass into an appropriate size paper bag (small or large sample). Label the bag with the name of the grass or variety, sample number (1, 2, 3, 4, and 5), and date. Record weight of sample, minus the tare weight of the bag, for each of the five samples to the nearest 0.10 lb or .10 gram.
9. Enter the five wet sample weights into the "Estimating Required Sample Size" calculator at the "Required Sample Size" tab on the GC Spreadsheet to determine if 5 samples achieved 10 percent of the sample mean with "t" value at 80-percent probability. If necessary, sample additional areas of the field to achieve the desired statistical accuracy. For additional guidance on using the sample size calculator, refer to the instructions in the "Required Sample Size" tab on the GC Spreadsheet.
10. Mark the sampling location with wooden stakes or plot markers with landowner's approval. Avoid temporary markers, such as engineering flags or tape, unless the area is wildlife protected or secured from vehicular traffic. Another option to prevent sampling the same areas is to establish an XY coordinate to pinpoint and navigate to areas of previously collected samples using GPS mobile data collection device.
11. Refer to section "Drying Procedures" below for drying samples.

Monthly and Yearly Harvests

Repeat the above procedure for subsequent monthly clippings or phenological growth stage for a minimum of 3 years with the anticipation that 1 of the 3 years will be a normal rainfall year. Record monthly rainfall totals at the site or from the nearest weather station. Even if rainfall limits the growth and production, continue the scheduled clippings to determine production in an abnormal rainfall year.

Residue Management

Remove the previous year's residue or standing biomass prior to regrowth or spring green-up using the recommended best management practice for the grass (e.g., mowing or burning). If mowing is the preferred management practice, mow the grass to the recommended cutting height. It may be necessary to rake the residue from the sampling area to prevent it from smothering the grass, which may cause dead spots in the sampling area or delay regrowth and prevent uniform green-up over the sampling area. Another option is to mow over the sampling area a few times to further clip and spread the residue over the sampling area.

Yield Determination

Small Samples

Small samples collected early in the growing season usually fit into a paper bag (#20–25, lunch size) and dried in a forced-air drying oven or air-dried. Enter the dry weight into the "Dry Weight Sample" column in the "Small Sample" worksheet of the GC Spreadsheet. See tab labeled "Small Sample" at the bottom of the worksheet or select the hyperlink for "Small Sample" on the "Field Information" tab. For yield calculations, select the sample frame size by selecting either 1.92 ft^2 or 4.8 ft^2 on the worksheet.

Larger Samples

As the grass increases in size and maturity, the amount clipped will likely be too large to fit into a #57 paper bag (grocery size) and complicate drying of the sample (refer to the section "Drying Procedures" below). Weigh the clipped grass to the nearest 0.10 lb and record the weight in the "Plot Weight" column in the "Large Sample" worksheet of the GC Spreadsheet. See tab labeled "Large Sample" at the bottom of the worksheet or select the hyperlink for "Large Sample" on the "Field Information" tab. Take a representative sample from the clipping (grab sample) to fill a #20–25 paper bag (lunch size) two-thirds full. For tall grasses such as switchgrass or big bluestem, bend or fold six to eight stems to fit into the paper bag (fewer samples depending on the size and length). If vegetative or reproductive stems are still too long, double fold grab sample to fit into a small-to-medium-size paper bag. Weigh the grab sample to the nearest 0.10 gram and record in the "Wet Weight Grab Sample" column. After the grab sample has properly dried, record the dry weight in the "Dry Weight Grab Sample" column. For yield calculations, select the sample frame size by selecting either 1.92 ft^2 or 4.8 ft^2 on the worksheet.

Drying Procedures

One of the biggest contributors of erroneous grass yield is failure to allow samples to properly dry prior to yield calculations. If drying samples in a forced-air drying oven avoid overloading the drier with too many samples. If there are more samples than the drier can hold, open the paper sack to allow the ambient air temperature to aid in partial drying of the samples until dried in the oven. Allowing air into the open paper bag will also prevent mold from accumulating on the sample.

Drying Oven

1. Place the sample bags in a drier oven at 55 to 60°C (oven temperature must not exceed 60 °C). Include an empty paper bag during the drying process to tare the scale prior to weighing the samples.
2. After 16 to 24 hours of drying, take two to three bags from different areas in the drier and allow them to cool at room temperature. Tare scales using the empty bag. Weigh samples and record weight. Dry for another 4 to 6 hours, remove from the drier, allow the bags to come to room temperature, and weigh the sample to determine if weight is less or constant. Repeat the procedure until sample weights are constant.
3. Record the dry weight of the sample to the nearest 0.10 gram or 0.10 lb, depending on the amount of the grass clipped.

Air Dry

1. Place the open bags in a closed environment such as a vehicle or in a room to dry. Another option to speed the drying process is to spread the samples evenly on a newspaper.
2. Include an empty paper bag with the samples to tare the scales prior to weighing.
3. After about 2 weeks of air-drying (the size of the sample will dictate drying time), weigh samples and record weight. Place samples back into the drying environment and continue weighing every 2 to 3 days until samples weights remain constant.
4. Record the dry weight of the sample to the nearest 0.10 gram.

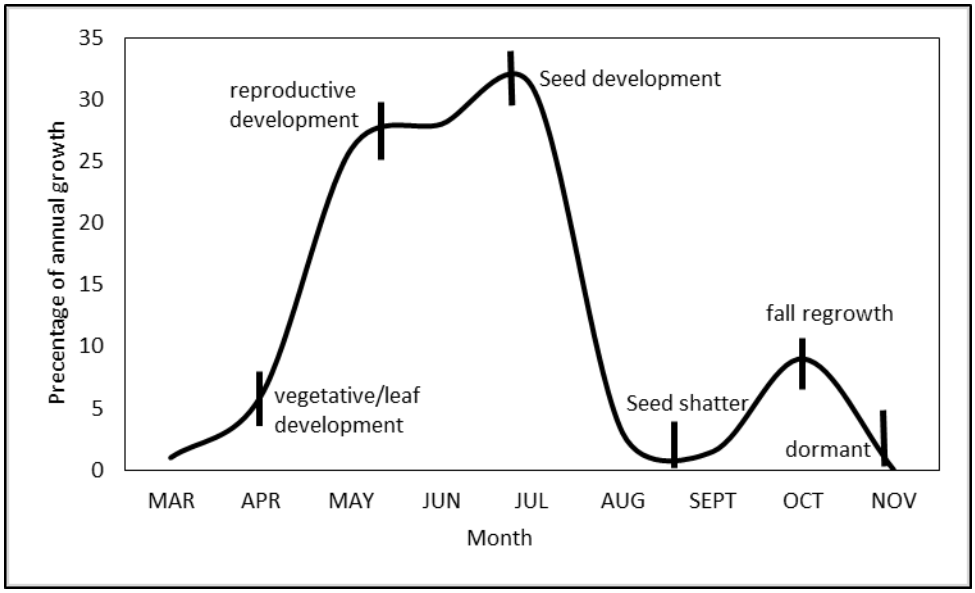
Data Archiving

Enter growth curve data into the Ecosystem Dynamics Interpretive Tool (EDIT), which serves as the primary repository of ecological site information produced by NRCS.

Figure 3: Example: Table of Monthly Biomass Yield, Accumulation and Loss, Growth Percentage and Phenological Growth Stage of Sideoats Grama (*Bouteloua curtipendula*) in Major Land Resource Area (MLRA) 78.

Month	Monthly Yield (lb/acre)	+/- Yield (lb/acre)	% Growth	Phenological Growth Stage
April	234	234	6	Vegetative/leaf development
May	1,200	966	26	Reproductive development
Jun	2,245	1,045	28	Seed development/ripening
Jul	3,423	1,178	31	Seed shattering/shattered
Aug	3,098	-325	0	Seed shattered
Sept	2,980	-118	0	Seed shattered
Oct	3,308	328	9	Late summer/early fall growth/ seed shattered
Nov	3,189	-119	0	Seed shattered
Total		**3,751**		

Figure 4: Monthly Percent Growth of Sideoats Grama in MLRA 78.



To calculate monthly yield increase of sideoats grama, subtract the current monthly yield from the previous monthly yield. For example, the April yield of 234 lb/acre is subtracted from the May yield of 1,200 lb/acre. Thus, the amount of yield produced for the month of May was 966 lb/acre (fig. 3). Continue determining the increase or decrease in yield from May to June, June to July, July to August,

etc. **Note**: The difference between the July–August, August–September, and October–November is a negative number, that indicates there were no yield increases as indicated by zero (0) during those months (fig. 3).

The total yield increase from April to November was 3,751 lb/acre. To calculate percentage growth of each monthly harvest, divide the monthly increase by the yearly total and multiply by 100 (figs. 3 and 4). For example, to determine the percentage growth in the April yield, divide 234 by 3,751, and then multiply the decimal by 100 to convert to a percentage. The percent growth from April to May was 6 percent.

References

Moore, K. J., L. E. Moser, K.P. Vogel, S.S. Waller, B.E. Johnson, and J.F. Pedersen 1991. Describing and quantifying growth stages of perennial forage grasses. Agron. J. 83:1073-1077.

USDA, NRCS. 1997. National Range and Pasture Handbook. Washington, DC.

Appendix 1

Phenological Growth Stage Descriptions[1]

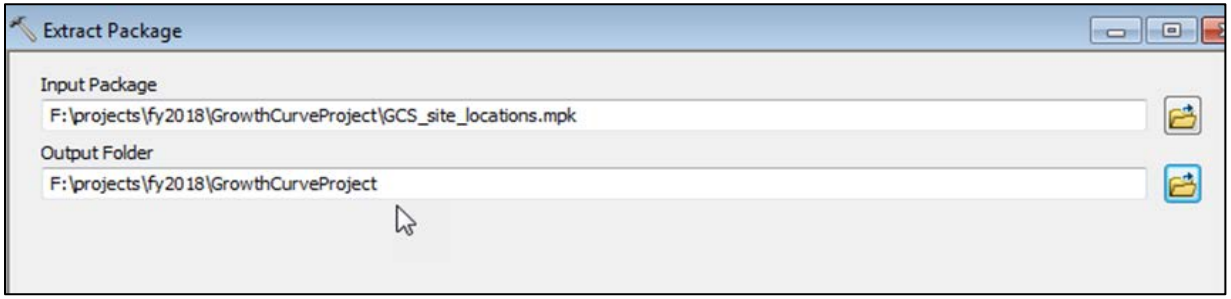
Growth Stage	Description
Vegetative/leaf development	1. emergence of first leaf 2. first and second leaf collar 3. 1 to 4 leaves
Stem elongation	1. beginning of stem elongation 2. stem elongation and first node visible 3. second node visible
Reproductive development	1. boot stage 2. inflorescence emerging – 1st spikelet visible 3. spikelets fully emerged 4. inflorescence emerged 5. anthers emerged/anthesis 6. post anthesis
Seed development and ripening	1. seed visible 2. milk stage 3. soft dough 4. hard dough 5. seed hard – physiological maturity 6. seed dry – ripe
Seed shattering	1. mature seed begins separating from the inflorescence 2. seed visible on the ground
Seed shattered	1. Mature seed shattered from the inflorescence 2. ≤10% remaining on the inflorescence

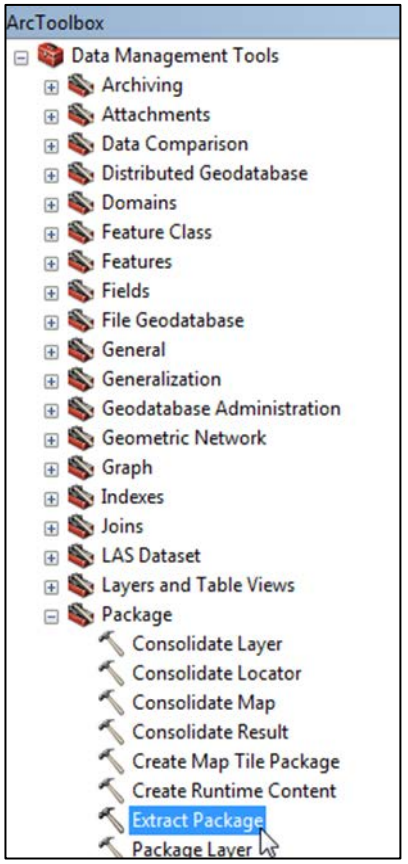
`11/ Adapted from Moore et al., 1991.

Appendix 2

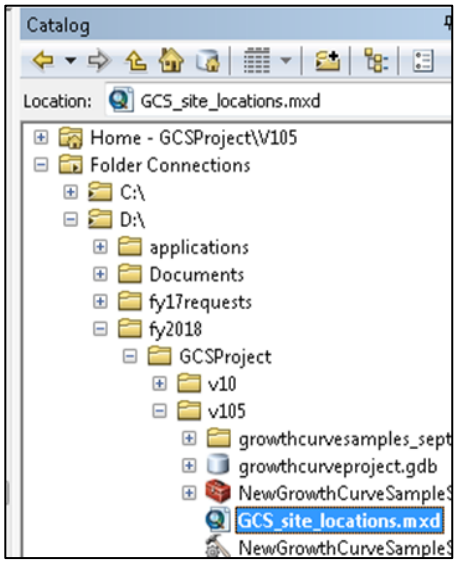
Instructions to Use Growth Curve Site (GCS) Location Model

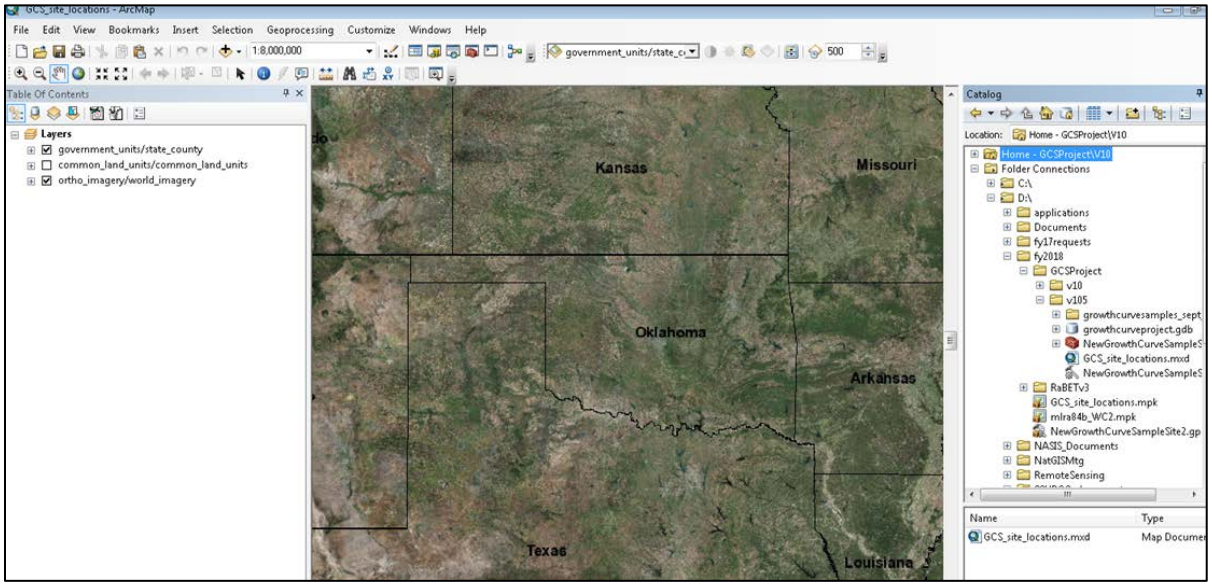
1. Click on the hyperlink to access GCS Location Model: https://usdagcc.sharepoint.com/:u:/s/nrcs_ssra/gis/EWDTjXals8tMgIh8b7K3JV0BXOes46LYAKSzmyCoNW9Afw?e=g7RjZ6
2. Download the zip file (GrowthCurveProject.zip) to the location of your GCS project on your computer or network. Open and extract the contents of the zip file. There will be an ArcGIS Map package file named "GCS_site_locations.mpk" and an ArcGIS Geoprocessing package file named "NewGrowthCrveSampleSite2.gpk." These files will need to be extracted using a tool in ArcMap. When extracted they will create a ready-to-use ArcGIS map document for the growth curve sampling project.
3. Open a new blank ArcMap session. If not already open, open the Toolbox application by clicking on the "Toolbox" button ."
4. In the Toolbox window, click on the + symbol to open the "Data Management" toolbox, then open the "Package" toolset and select "Extract Package" tool.
5. In the "Extract Package" window, click on the folder button next to the "Input Package" parameter and browse to the location of the package. Select "NewGrowthCrveSampleSite2.gpk." Then click on the folder button next to the "Output Folder" parameter and browse the GCS project location.
6. Repeat the process for the "GCS_site_locations.mxd."



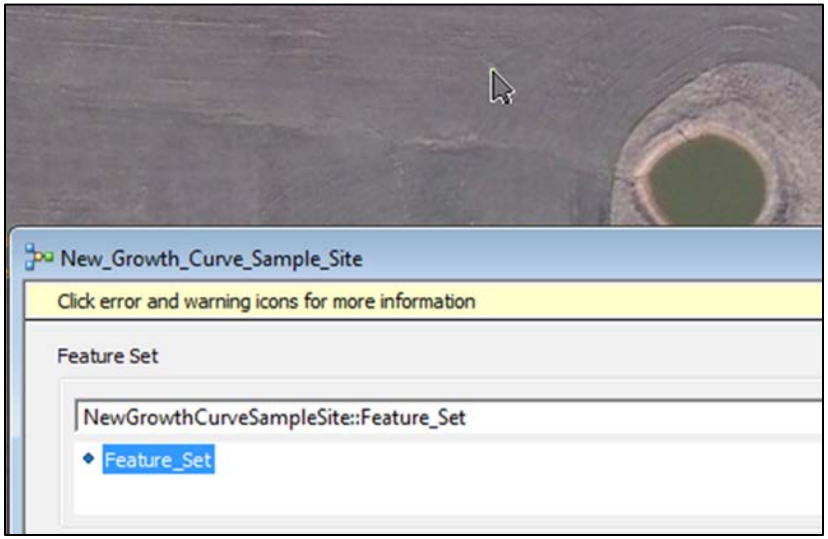


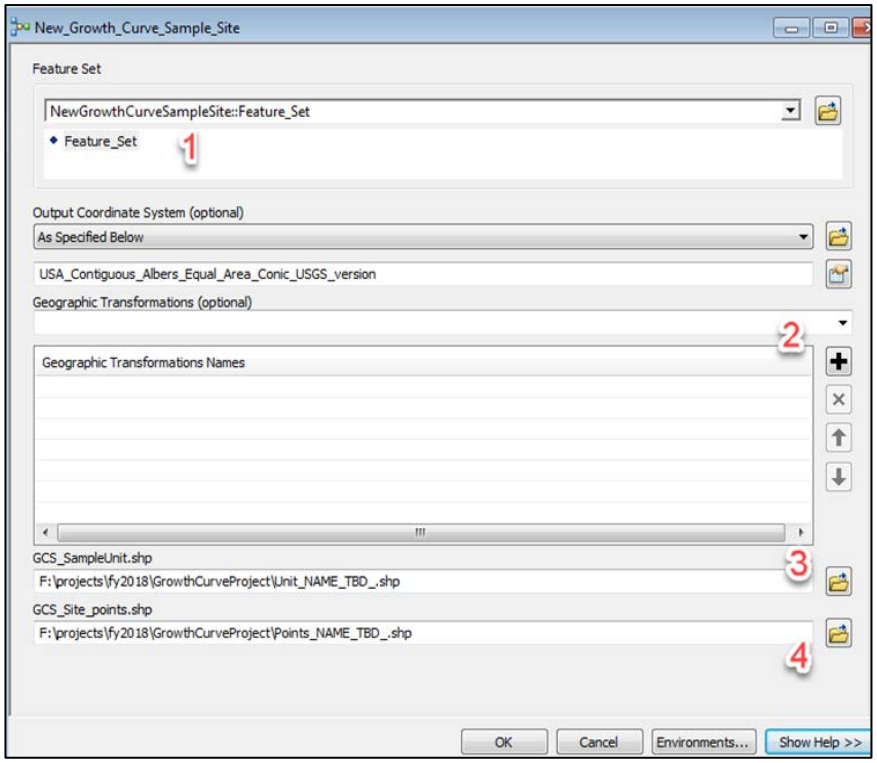
7. If not already open, open the Catalog application by clicking on the "Catalog" button  . In the Catalog directory pane, browse to the "GCS Project" folder where the packages were extracted to and click on the + symbol to open the folder. If you are using ArcGIS 10.5.x, and then open the "v105" folder, then click on the "GCS_site_location.mxd" file. If you are using an older version of ArcGIS, open the "v10" folder. The tools should work in either version of the ArcGIS software.
8. The map should have the "State and County Boundaries," "Imagery," and "Common Land Unit Boundaries" in the Table of Contents. Navigate in the map to the location of the field to be sampled. You can use the "Locate" tool  or the "**XY**" tool  to find the location.



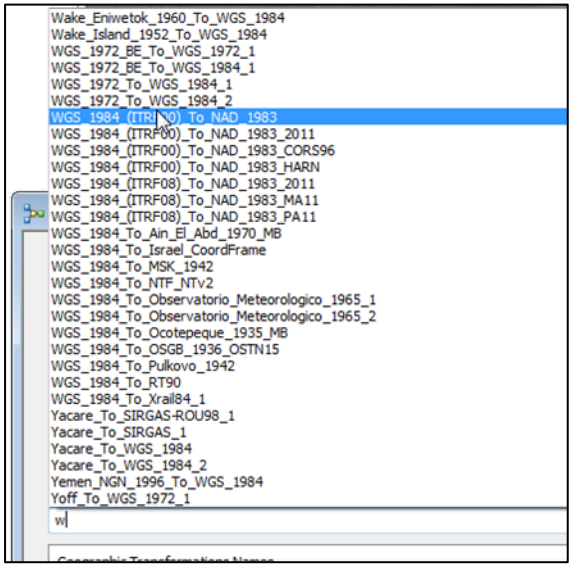


9. In the Catalog window find the "v105" folder again and open the "NewGrowthCurveSampleToolbox." Double click on the "New _Growth_Sample_Site" model.
10. There are 4 steps to complete to run this process.
    a) Click on the "Feature Set" symbol in the 1st window. Move the cursor to the map location in the field where you want the center of the 50-ft sample unit created. The cursor will have a transparent arrow symbol when the "Feature Set" function is active. Click one time to place the centroid of the sample unit in place.





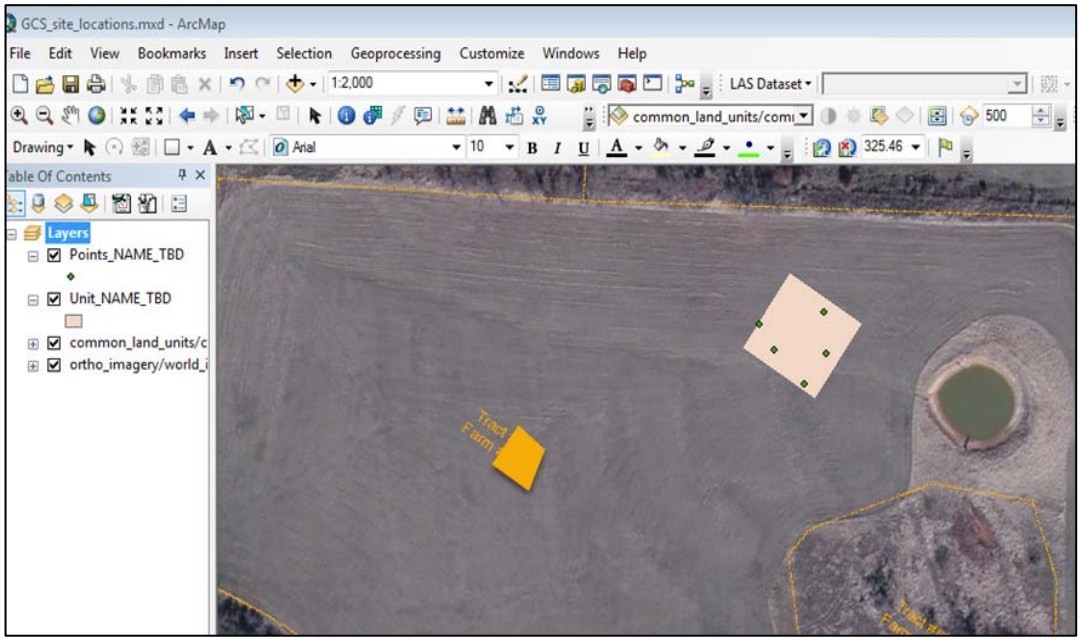
b) In the "Geographic Transformations" (optional) window, click on the drop-down arrow and press the "w" key on your keyboard to automatically move down the list to the "WGS_1984_(ITRF00)_to_NAD_1983" transformation. Click on this transformation and it should display in the selection window.



c) Browse to the location in your computer or network where the growth curve project data is stored and enter the name of the growth curve sampling unit. According to this workflow process this unit feature will be used to collect random samples multiple times a year for a period of 3 years. The formal naming convention for this polygon feature class has yet to be determined.

d) Browse to the location in your computer or network where the growth curve project data is stored and enter the name of the growth curve sampling points. According to this workflow process these point features will be the location to collect one set of vegetation samples during a period of 3 years. The formal naming convention for this point feature class has yet to be determined.

11. The output of the model will have the unit polygon and the sample points feature classes in the Table of Contents. This point file can be downloaded to a Garmin GPS receiver using the "Features to GPX" tool for navigation to these locations for sampling.
12. A different model will be made available for creating random points within the existing sampling unit area for collections after the initial sampling occurs.



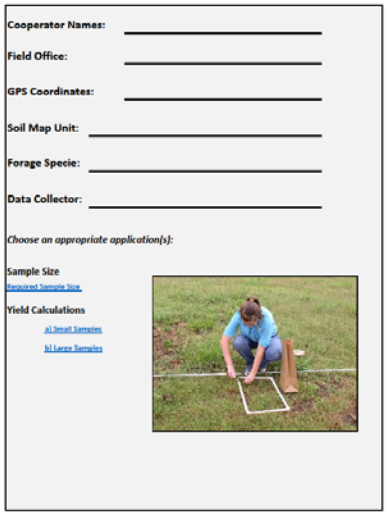
Appendix 3

Growth Curve Procedure Spreadsheet

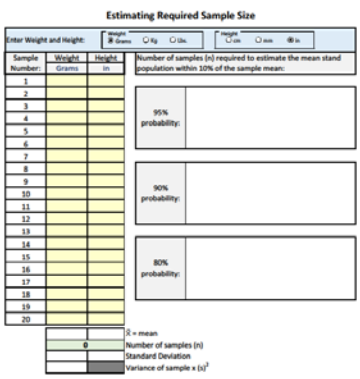
The Excel file referenced in this TN is available for download and use.

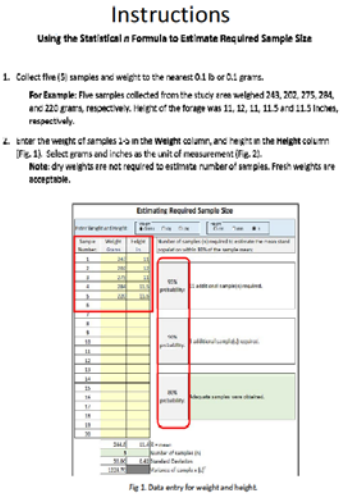
Below are images of the individual worksheets in the Growth Curve spreadsheet.

Field Information Worksheet



Required Sample Size Worksheet





Large Sample Worksheet

Yield Calculation

Use this form when sample is too large to fit into a single lunch or grocery size paper bag. Remember to tare scales with an empty paper bag that has been dried with the samples prior to weighing grab samples.

Date:		Rainfall (inches):	
Forage Specie:			
Phenological Growth Stage: (*choose from drop-down context menu*)			
		Select frame size:	◉ 1.92 ft2 ○ 4.8 ft2

Sample#	Plant Height (inches)	Plot Weight (lbs.)	Wet Weight grab sample (grams)	Dry Weight grab sample (grams)	% dry matter (decimal)	Yield (lb/acre)
1					0.000	
2					0.000	
3					0.000	
4					0.000	
5					0.000	
6					0.000	
7					0.000	
8					0.000	
9					0.000	
10					0.000	
11					0.000	
12					0.000	
13					0.000	
14					0.000	
15					0.000	

Small Sample Worksheet

Yield Calculation

Use this form when sample is small enough to fit into a lunch or small grocery size paper bag. Remember to tare scales with an empty paper bag that has been dried with the samples prior to weighing.

Date:		Rainfall (inches):	
Forage Specie:			
Phenological Growth Stage: *(choose from pull down context menu)*			
		Select frame size:	◉ 1.92 ft2 ○ 4.8 ft2

Sample#	Plant Height (inches)	Dry Weight Sample (grams)	Yield (lb/acre)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
Average	0.0		0