



# EXERCISE 4

## Lidar Vegetation Metrics: Creating and Using a CHM from a LAS Dataset

### Introduction

In the previous exercises you learned to create and filter a LAS Dataset, and use it to create bare earth rasters. In this exercise you'll use similar tools to examine the vegetation canopy, rather than the bare earth surface. First you will create a highest hit raster from the first returns in the LAS Dataset. You will then couple that with the bare earth DEM that you created in the last exercise to create a canopy height model.

### Required Data

- Digital Elevation Model (DEM) created in exercise 2

### Prerequisites

- Completion of Exercises 1, 2, and 3





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## Part 1: Opening and Filtering LAS Dataset

Before you begin creating canopy rasters, you need to make sure you have your LAS Dataset open in ArcGIS Pro, and that you have it filtered correctly. You learned how to do this in previous exercises, but as a review these steps will walk you through how to do that.

### A. Open ArcGIS Pro and Load a Map

1. Launch ArcMap from the start menu by clicking **Start, All Programs, ArcGIS, ArcGIS Pro, ArcGIS Pro**.
2. In the window that opens, you can either create a new project or load the project you created in the last exercise. If you start a new project, click **Blank** in the **Create a new project** pane on the right.
3. In the Create a New Project pop-up, give the project a name. You can save the project location as the default.
4. Click **Ok**.
5. In the upper left corner click **New Map**. If you don't see the New Map button, make sure you're on the **Insert** tab on the top pane.

### B. Load and filter LAS Dataset

1. In the toolbar at the top, click the **Map** tab.
2. Click the **Add Data** button.
3. In the explorer window, navigate to the **GTAC\_lasd\_training.lasd** LAS Dataset that you created in the first exercise.
4. Click **OK** to open the dataset.
5. Because you're going to be creating bare earth products from the LAS Dataset, you'll need to filter out the non-ground points. Fortunately, you've already learned to do this in the previous exercise. Make sure you have the LAS Dataset selected in the table of contents in ArcGIS Pro. Then click the **Appearance** tab in the toolbar at the top of your ArcGIS Pro window.
6. In the **filters** section, click the **LAS Points** dropdown.
7. In the dropdown, select **First Return Points** to filter out all the points except for the highest hit surface. These will be the points you need to create the canopy products later in the exercise.

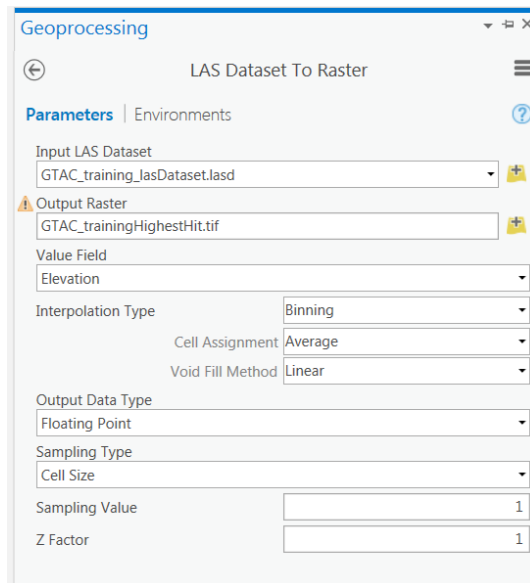
## Part 2: Creating Canopy Products

Unlike a bare earth raster or highest hit raster which represents elevation values, a Canopy Height Model (CHM) represents actual heights of objects. For example, if a pixel in the highest hit raster has an elevation of 2010 meters, and the value of the same pixel in the DEM has an elevation of 2000 meters, subtracting them will show you that the tree in that pixel has a height of 10 meters. This section of the exercise will teach you how to create a highest hit raster and use that in conjunction with the DEM you created in the last exercise to create a CHM.

### A. Creating a Highest Hit Raster

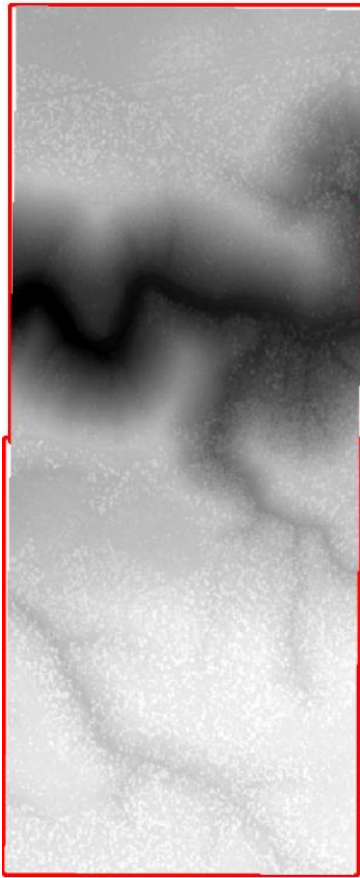
In the previous exercise you used the LAS Dataset to Raster tool to create a bare earth DEM by filtering your LAS Dataset to just the ground points. Now you have your LAS Dataset filtered to just first returns, so when you use the LAS Dataset to Raster tool, the raster output will be made from the first return points, making it a "highest hit" raster.

1. Make sure that you have completed the previous section so that you have the **GTAC\_lasd\_training** dataset loaded and you have it filtered to the first return points only.
2. In the toolbar at the top of your ArcGIS Pro window, click the **Analysis** tab.
3. In the Geoprocessing section, click **Tools**. This will open the geoprocessing pane.
4. In the "Find tools" search bar, type **LAS Dataset to Raster**.
5. Click the **LAS Dataset to Raster (Conversion Tools)** tool in the search results. This will open the tool in the geoprocessing pane.
6. In the "Input LAS Dataset" section, click the dropdown button on the right, and select **GTAC\_lasd\_training.lasd**, which you have loaded and filtered to first return points.
7. The "Output Raster" field will automatically fill with a default name, and will be output to a default location. Click the yellow icon next to the Output Raster box. This will open an explorer window. You can choose the location to save the raster. Name it **GTAC\_trainingHighestHit**.
8. The rest of the settings you can leave as their default for now. At the bottom of the pane, keep the "Sampling Type" as Cell Size. But in the box below that, change the "Sampling Value" to **1** (this will make the output raster the same resolution as your DEM). The image below shows the settings you should use for this exercise.



9. The rest of the settings that you didn't change in the LAS Dataset to Raster pane adjust how the highest hit raster values are interpolated from the lidar points. These options will change the values in the raster, so when you create one for your own project you should determine what the best setting for you are. You can read about them here: <http://pro.arcgis.com/en/pro-app/tool-reference/conversion/las-dataset-to-raster.htm>
10. Click **Run**. The tool will take a few minutes to create the highest hit raster.

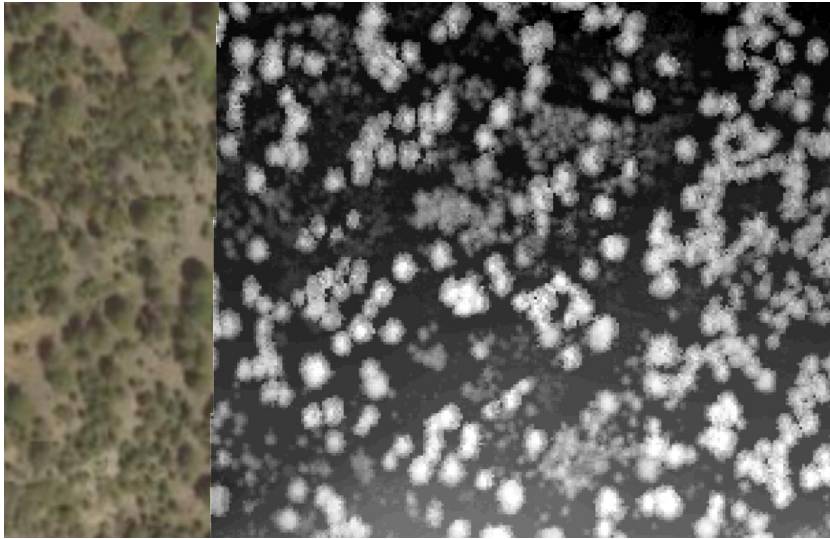
11. When the tool is finished running it will look similar to the image below:



Notice that it looks very similar to the DEM you created in the previous exercise. It follows the same spatial patterns, but it will have a more speckled pattern. These "speckles" are the vegetation, or other above ground objects that you've included in this raster. You'll get to examine them more in the next steps.

## B. Inspect the Highest Hit Raster

1. In the **Map** tab at the top of ArcGIS Pro, click the **Add Data**.
2. In the explorer window that appears, **navigate** to the course data folder that you downloaded. Click the **Naip2015.tif** image. Click **Ok** to add the image to the map.
3. In the table of contents pane on the left, click and drag the **NAIP** image below the **highest hit** raster.
4. Zoom to an area where you can see vegetation in the highest hit raster.
5. Click on the **highest hit** raster in the table of contents to select it.
6. With the highest hit raster selected, click the **Appearance** tab in the toolbar at the top of the ArcGIS Pro window.
7. In the Appearance tab, click **DRA** in the rendering section. This changes the symbology so that the pixels will be stretched based on the values in your zoomed map window, which will make the trees more visually distinct.



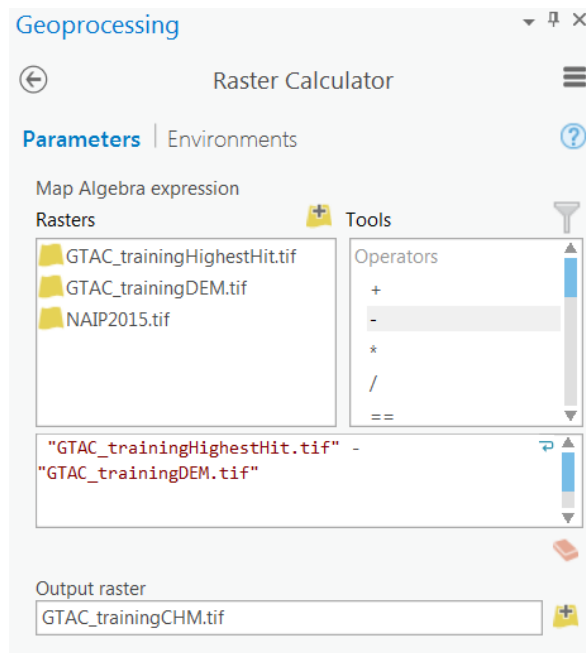
8. In the Effects section of the Appearance tab, click **Swipe**.
9. With Swipe selected **Click and Drag** your cursor back and forth or up and down to swipe the highest hit raster on and off. You'll see the highest hit raster aligned with the vegetation in the NAIP image.

## C. Creating a Canopy Height Model (CHM)

Recall that you'll need to subtract the DEM from the highest hit surface to create the CHM. You'll learn to do that here.

1. In the **Map** tab in toolbar at the top of ArcGIS Pro, click **Add Data**.
2. In the explorer window that appears, **navigate** to the DEM that you created in the last exercise. Click the **GTAC\_trainingDEM** image. Click **Ok** to add the image to the map.
3. In the **Analysis** tab in the toolbar at the top of ArcGIS Pro, click **Tools**. This will open the Geoprocessing pane.
4. In the Find tools search bar, type **Raster Calculator**.
5. Click **Raster Calculator (Spatial Analyst Tools)**. This tool allows you to do pixelwise calculations of the images we have loaded.
6. In the "Rasters" section of the raster calculator tool, double click the **GTAC\_trainingHighestHit** raster to add it to the equation.
7. In the "Tools" section under operators, double click the **-** sign to add it to the equation.
8. In the "Rasters" section, double click the **GTAC\_trainingDEM** raster to add it to the equation.
9. The "Output Raster" field will automatically fill with a default name, and will be output to a default location. Click the yellow icon next to the Output Raster box. This will open an explorer window. You can choose the location to save the raster. Name it **GTAC\_trainingCHM**. The tool should look like the image below.

**Note:** If you're saving the raster outside of a geodatabase, you'll have to give it a shorter name. ESRI only allows you to have 13 characters in the output file name. If you run into this issue, you can give the output raster a shorter name (simply trainingCHM, for example). You'll just need to remember where you've saved it and what name you've given it



10. Click **Run**. When the tool is finished it will add the CHM to the map. The CHM will look very similar to the highest hit raster visually, but notice that its maximum value is only 58. This is because the values in this raster are representing the heights of vegetation, not the elevation of vegetation. You may also notice that there are negative values. This is because of the way the rasters values were interpolated from the LAS Dataset. However, if you find the negative pixels in the image, you'll see that they are relatively uncommon. The next section of the exercise will show you how to remove the negative values and create a raster that vegetation cluster segments can be derived from.

## Part 3: Segmenting Tree Clusters

In this section of the exercise you're going to learn to use the ArcGIS pro segmentation tools to examine trees in the CHM that you created in the previous section. ArcGIS Pro has some built-in rudimentary segmentation tools that you're going to use to segment individual trees.

### A. Threshold the CHM

Before you use the CHM to segment trees, you should set it up so that you're not including any pixels other than those representing trees. In the steps below you'll use the con tool to filter out unneeded pixels.

1. In the **Analysis** tab in the toolbar at the top of ArcGIS Pro, click **Tools**. This will open the Geoprocessing pane.
2. In the **Find tools** search bar, type **Con**.
3. Click on the **Con (Spatial Analyst Tools)** tool when it appears in the search results to open it.

4. In the Input conditional raster dropdown, click the down arrow and add **GTAC\_trainingCHM.tif** that you created in the previous section as the input conditional raster.
5. In the Expression section, click the **SQL** icon.

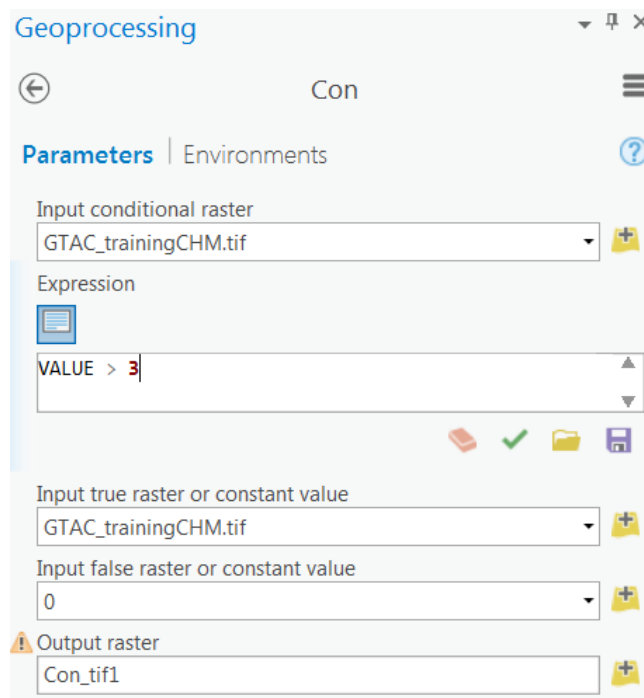


This will allow you to enter an SQL expression for the Con tool.

6. In the expression window, type **VALUE > 3**. When you execute the Con tool, this expression will mean that the tool applies to all pixels where the value is less than 3 meters. When you're doing this on your own data, you need to be aware of your forest to know how to threshold the height. In some forests, a height cutoff of 3 might be too high, in others it may be too low.

**Note:** When entering the expression, if you start typing an SQL expression, possible options will appear. So in the expression window, if you type "v", the VALUE option will appear, and you can click on it to add to the expression.

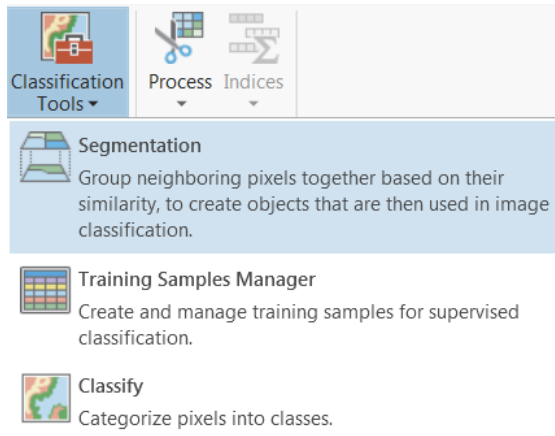
7. In the Input true raster or constant value dropdown, click the down arrow and select **GTAC\_trainingCHM.tif**. This means that where the expression is true, and the values are above 3, they will stay the same.
8. In the Input false raster or constant value, enter **0**. This means that every value below 3 will get a value of 0.
9. For now you can leave the Output raster as the default. Click **Run**.



The output from the Con tool will look very similar to the CHM from before. But you'll notice that the new low value is 0. This means that all the erroneous negative values from before are removed, and values below 3 are set to 0.

## B. Using segmentation tools

1. Make sure that you have the output from the Con tool selected in the Table of Contents.
2. Click the **Imagery** tab in the ArcGIS Pro toolbar.
3. In the imagery tab, click **Classification Tools**. This will open a dropdown. Click **Segmentation**.



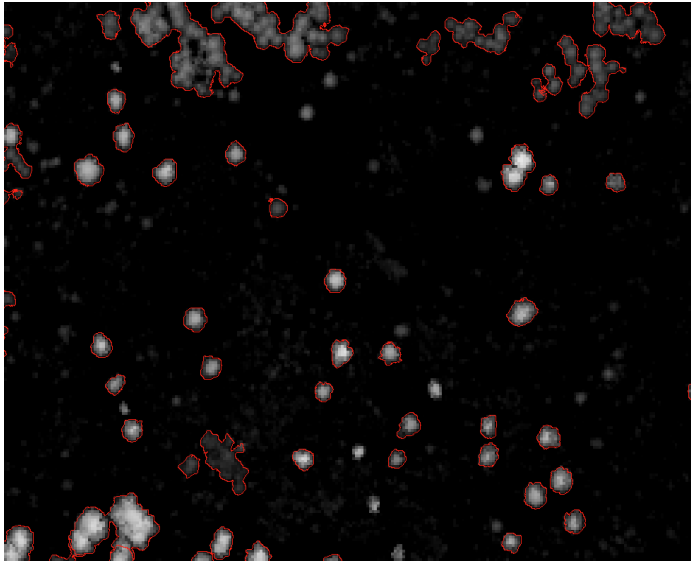
4. When you click segmentation, the Image Classification pane will appear. Here you can adjust the "Spectral detail" and "Spatial detail".

**Note:** *Spatial and Spectral detail adjust how much you want the segmentation to depend on the shape of the features in the image, or the image pixel values. But how the detail is calculated is proprietary to ESRI, so be aware that when you use this tool, you don't know exactly how the segments are created, which makes it difficult for these methods to be repeatable and describable when using the segmentation tool on your own data. You can read more about ArcGIS Pro segmentation here: <https://pro.arcgis.com/en/pro-app/help/analysis/image-analyst/segmentation.htm>*

5. In the segmentation pane, check the box that says **Show Segment Boundaries Only**.
6. Click **Preview** at the bottom of the pane. When you do this you should zoom to a small area of the image, so that the preview will load more quickly. The preview layer will appear in the table of contents.
  - i. *Optional:* The segment boundaries may be difficult to see. You can change the symbology of the preview layer to be more visible. Click the colors of the preview layer in the table of contents. In the symbology pane that appears, change symbology from RGB to stretch. Then change the Color Scheme to something that will show a more visible colors. One good option is a tri-color option, below:



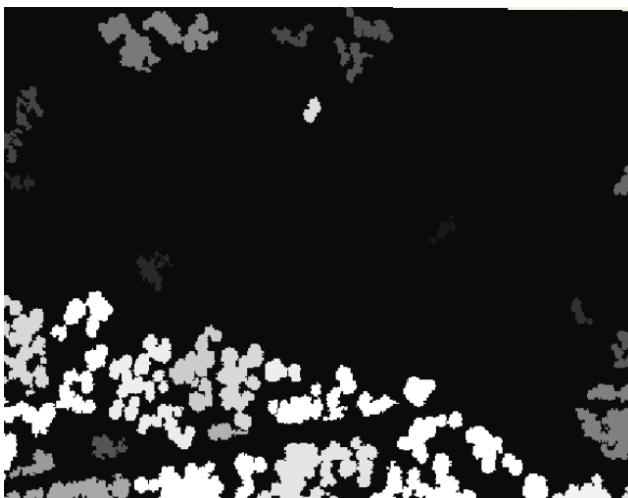
7. The trees that you're segmenting don't have the same blocky effect as the pixels in your CHM, and they stand out distinctly from the 0 values of the ground. This means that the spatial and spectral detail can both be reduced. In the segmentation pane, drop the **spectral detail** and the **spatial detail** to 2.
8. Change the **Minimum segment size in pixels** to 100.
9. The preview will take a moment to load, but when it does you'll see something similar to the image below.



10. You'll notice that when trees are close together, they're included in the same segment. These settings give more "tree cluster" segments, rather than just tree segments. Adjusting the spectral detail will start to make individual tree segments, which you can experiment with if you'd like, but if you'd like to cluster individual trees more effectively you'll likely need to use a software such as eCognition or Fusion.
11. Name the output dataset **segmented\_trees**.

**Note:** If you get the error 0001921 this means that ArcGIS is requiring a file type to know how to save the file. Type .tif at the end of your file name and try again.

12. Click **Run** to create the final segment layer. Segments are processing intensive and will take a few minutes to run. When they have you will end up with a segmented raster image, where each tree cluster is assigned a unique value.



13. *Optional:* If you'd like to convert this segmented raster to a shapefile, you can open the **Geoprocessing** pane as you've done earlier in the exercise and use the "Find Tools" search bar and type **Raster to Polygon**.

- i. In the Input raster section, click the dropdown and add the **segmented\_trees** raster that you created above.
- ii. You can leave the Field section **Value**.
- iii. Give a name to the Output polygon features.
- iv. Click **Run**. This will output a new layer where each segment in the raster is represented as a polygon.

## *Part 4: Making Strata Metrics (Optional)*

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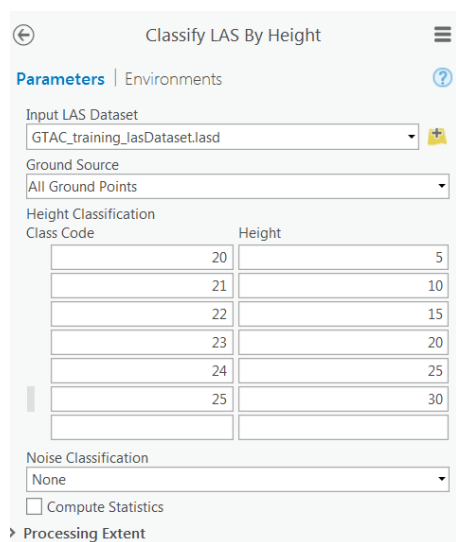
So far you've taken time to look at the lidar point cloud, and seen that all the points are accurately located in three dimensions. This is what lets us measure tree height and ground height from lidar data. To this point, you've only looked at the top of the canopy (the highest hit surface) or you've removed all but the ground points and looked at just the bare earth surface. But occasionally you may want to look at points that are located at a specific section of the canopy. For example, maybe you want to look at vegetation density in the lower canopy, from 1 to 5 meters. This is called a canopy strata layer.

In this part of the exercise you'll learn to specify what the height cutoffs for your strata layers are, and how to extract information from those strata layers.

### **A. Assign Height To LAS Codes**

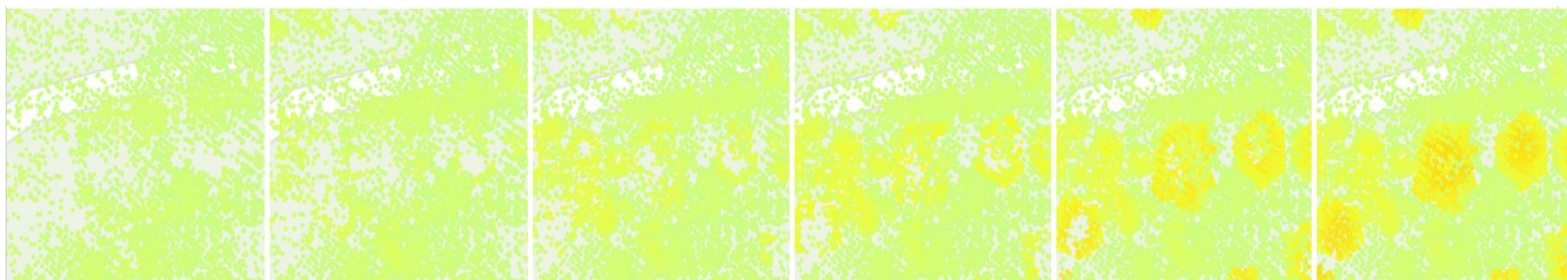
To understand how to use ArcGIS Pro to create strata layers, you need to remind yourself about classification fields in las files. Each point has a horizontal and vertical location, but also has a class code. The class code can define what the surface is. For example, all points with class code 2 are ground points. If the point has a class code 9, the point is on water. Las 1.4 files leave some las class codes be user definable. ArcGIS Pro has tools to let the user define those codes based on the height of the point, which is what you're going to do in the section below.

1. In the contents pane on the left in ArcGIS Pro, click on the **GTAC\_lasd\_training** layer you have loaded to highlight it.
2. In the **Analysis** tab in the toolbar at the top, click **Tools** to open the **Geoprocessing** pane.
3. In the search bar at the top of the Geoprocessing pane, type **Classify las by height**.
4. Click on **Classify LAS By Height (3D Analyst Tools)** to open the tool.
5. In the Classify las by height tool click the dropdown button on the right side of the Input LAS Dataset box, then click on the **GTAC\_lasd\_training** file to add it as the Input LAS Dataset.
6. Leave the Ground Source as All Ground Points.
7. In the **Height Classification** section, you're going to define classes 20-25 by height in 5 meter increments. In the **Class Code** column enter numbers **20-25** and in the **Height** column enter numbers **5-30**, as seen in the image below.



Class Code	Height
20	5
21	10
22	15
23	20
24	25
25	30

8. You can leave the rest of the options at their default. Click **Run**. The tool will take several minutes to finish.
9. After the tool runs you should visualize the points that you just classified. Remember that you classified the LAS codes 20 through 25. Double click on the **GTAC\_training\_lasDataset** in the table of contents pane to open up the properties of the layer. In the properties menu, click **LAS Filter**.
10. Remember the LAS filter menu that you first learned to use in Exercise 1. Open that, then begin by unchecking all the classes except for class 20. Click OK. Then visualize the points. Do the same thing for the rest of the codes that you classified in the previous steps. You'll see how the codes were classified by height, similar to the image below.



11. Just like you learned earlier in the exercises, you can filter the LAS Dataset to only one of the class codes (one of the strata layers) and then create rasters from the data based on the subset of the points.

**Congratulations!** In this exercise you used some familiar tools to generate new products. The first return LAS Dataset filter was coupled with the bare earth surface created in the last exercise to create a Canopy Height Model (CHM) which is an essential metric when using lidar for forestry. There are a number of things that can be done with the CHM including tree cluster segmentation, which you also learned about in this exercise.