LOCATING DOWNED LOGS BENEATH FOREST CANOPY USING AERIAL LIDAR

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Summary

This workflow was used for a test project. This project was to look into the use of Aerial LIDAR data from both drones and planes to locate downed logs, underbrush, and rocks on the forest floor. LIDAR was used because it allowed for penetration of vegetation. This process explains where the data was collected and how it was processed within ArcGIS Pro to get layers that show the undergrowth on a forest floor. All the work for this project was done in the ESRI suite, in specific ArcGIS Pro.

Data Collection

This data was taken from PASDA.com. On site, click the "apps and tools" tab on the top navigation bar. Then click on the Pennsylvania LiDAR Navigator Portal. Once within this portal there are a few different things that can be done. The best method to locate where the study area will be is to use the search feature at the top left of the screen. Once the study area is located, turn on the correct LiDAR layer on the "Layer's list" dropdown menu on the right hand of the screen. This shows black gridded boxes on the map that can be clicked and will allow download of the LAS files for the tiles that cover the boundary area.

In this case, Rickets Glen State Park was the study area chosen for the project. This required use of the PA LIDAR Navigator to select 4 USGS QL2 2017 tiles and download the LAS files. These tiles used were 8TUL393575.las, 18TUL393573.las, 18TUL391575.las,18TUL391573.las.

Data Processing

Step 1. *Create LAS Dataset*

Once all LAS files are imported into ESRI ArcGIS Pro software. Go to the "View" tab and click on the red toolbox icon that says "Geoprocessing" within the "windows" section. In the search menu type in "Create LAS Dataset (Data Management Tools)". In the "Input Files" section add all the LAS files needed. Chose the output location and name, and also change the coordinate system to whichever is needed. (Refer to Figure 1)
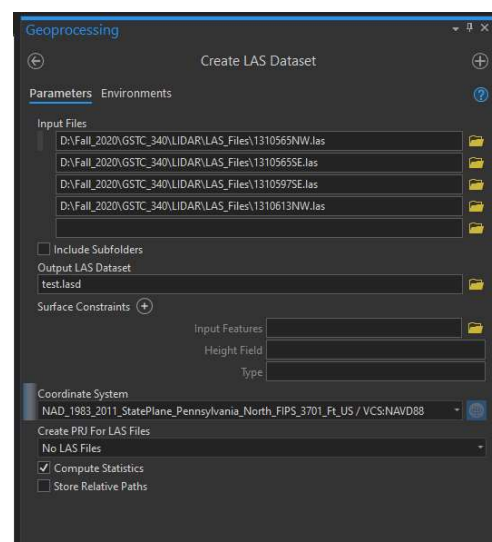

Figure 1. Create LAS Dataset tool.

Step 2. *LIDAR Point Classification*

LIDAR classification can help separate LiDAR points to be used in certain instances and layers. In order to find the ground returns and the last returns to see the downed logs, the classification by height must be done to cut off the unneeded points. While still on the "Geoprocessing" tab type in Classify LAS by Height and click on the "Classify LAS by Height (3D Analyst Tools) " tool (Figure 2). Add the .LASD that you created in Step 1 into the "Input LAS Dataset". Then for the class code you just need an ID to then represent the custom height you type into the "Height" field. There must be a "Class Code" and "Height". The other fields are optional. Once completed you will be able to go into the symbology tab and change the colors that represent each classified point section. (Figure 3)
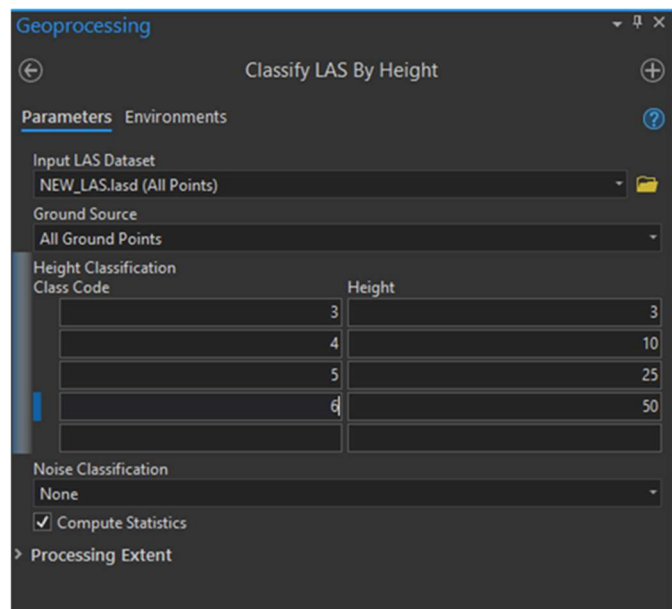

Figure 2. Classify LAS by Height Tool

Figure 3. Classification separation

Below are 4 photos of the study area in Ricketts Glen State Park. The Dark green represents the high vegeation that was at 25-50 feet. The light green represents for the medium vegetation which was at 10-24 feet. The Low vegetation was purple and ranged from 3-9 feet. The ground was 0-2 feet. These numbers can be tweaked to get the proper distance in the Classify LAS by height tool. The two photos at the bottom of the page show the Low Veg layer and the logs can barely be seen.

NOTE* The Tool will run for a long time depending on the amount of points in the LASD file. If using data that has high point density points use a sample study area to make sure everything is running corrctly if expirimenting with height classification.
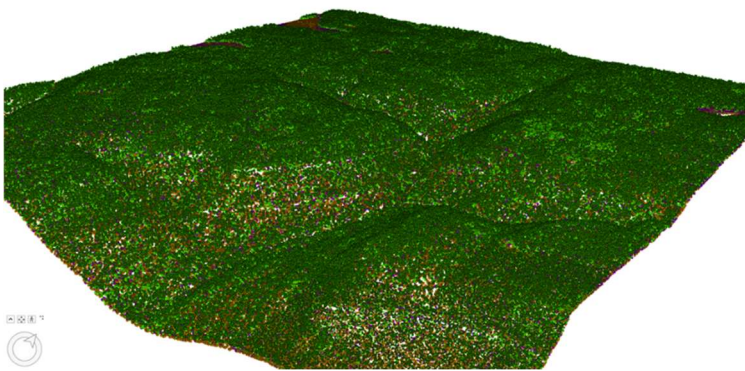

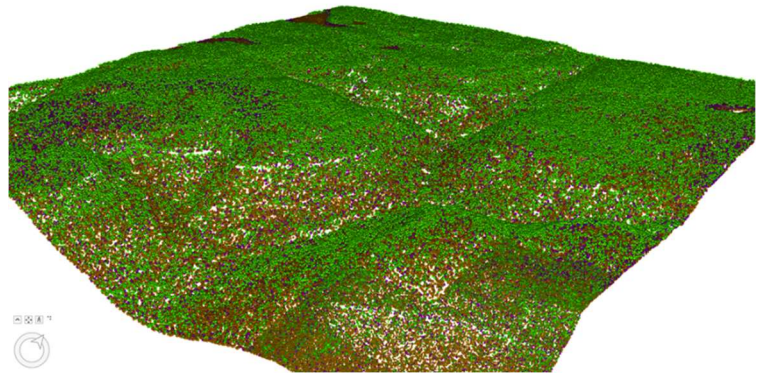*Figure 4. High Vegetation LiDAR Classification*

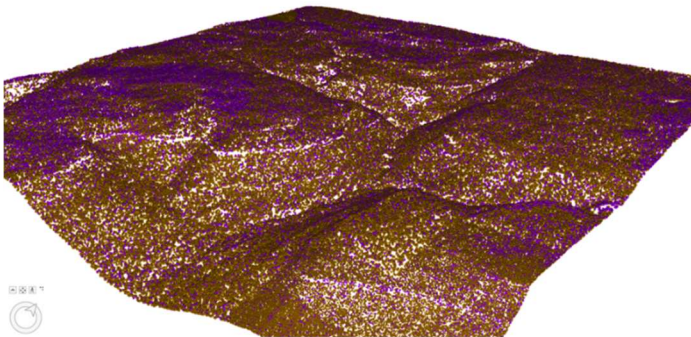*Figure 5. Medium Vegetation Classification*

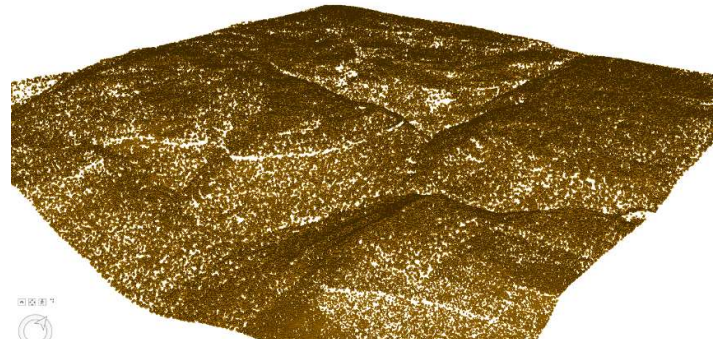*Figure 6. Low Vegetation Classification*

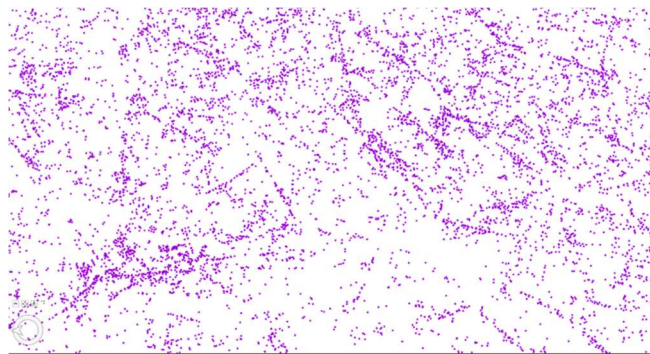

Figure 7. Ground LIDAR Classification

Figure 8. Low vegetation Layer showing downed logs

Step 3. *LIDAR Statistics*

LIDAR statistics provide a good amount of information that can be useful for different situations. One of the results from these stats is the ability to know the point spacing. This is important to know the density of the points but also it will be useful for a tool run later on. Knowing this number allows for the future tool to run resolution calculations correctly.

First, you need to click again on the "View" tab and select "Geoprocessing" which is located in the windows section. Then search for "LAS Dataset Statistics" in the toolbox (Figure 9). This will pull up a tool that has two dropdown menus. The only one that needs to be filled is the "Input LAS Dataset" which is the one that has been created from the 4 tiles in step 1 and 2. Hit Run and let it process.
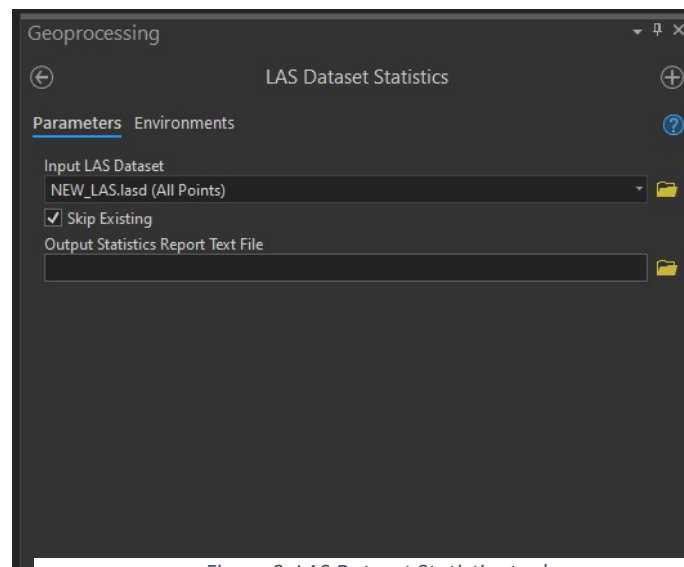

Figure 9. LAS Dataset Statistics tool

This will add to the "Contents" tab on the left side of the screen. However, to get the full data click on the "View" tab and click "Catalog View". This will bring up a new page. Navigate your folders or Geo-Databases to find where the LASD file is saved. Click on it and select properties. Once in the new menu, select "Statistics" (Figure 10). This will give all the information on the LASD file including classification code stats, return information, and attribute information. There is useful info in here. Go back to the LAS Dataset Properties menu and click "LAS Files".

This option should be right under the Statistics option in the menu (Figure 11). In the red box in figure 11 is the point spacing information for each LAS title that was merged into the LASD file. Keep this number in mind for step 5.
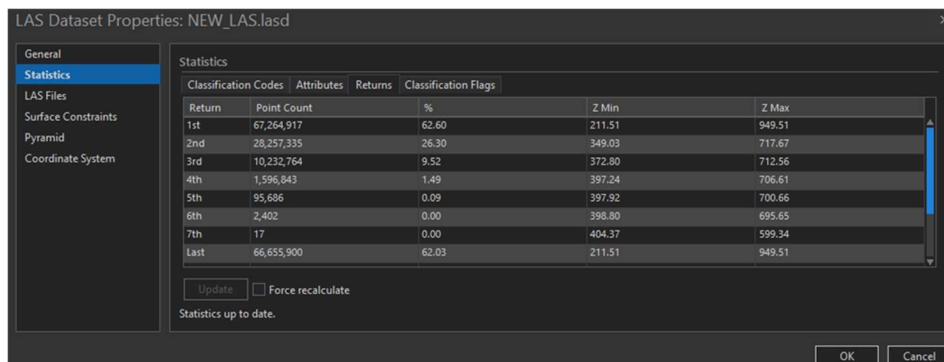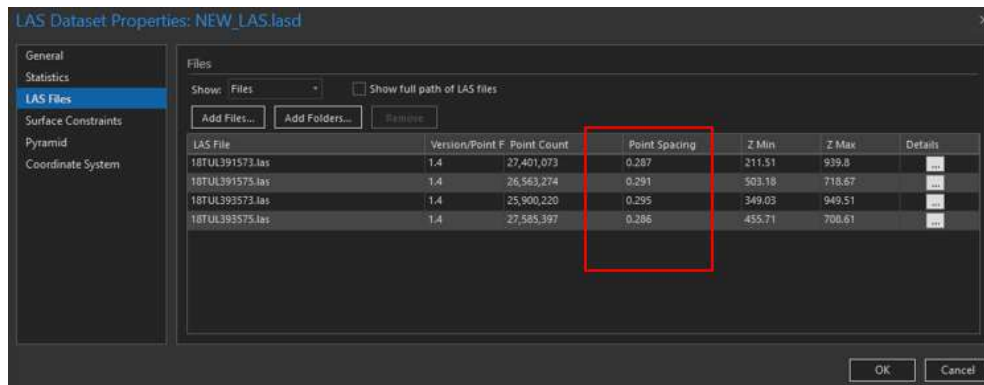

Figure 10. Statistics tab in the LASD properties menu

Figure 11. LAS Files tab in LASD Properties menu

Step 4. *LAS Dataset Layer Creation*

The next step is to create layers from the LIDAR classification codes. The idea is to use the ground LIDAR code to create a ground layer. Additionally, using the Last Return code to make a Last return layer. These will be used later to create DEM and DSM rasters.

First, you need to click again on the "View" tab and select "Geoprocessing" which is located in the windows section. Then search for "Make LAS Dataset Layer" in the toolbox (Figure 12). Then for the "Input LAS Dataset" use the dropdown to put in the LASD that was created in steps 1 and 2. The "Output Layer" option can be whatever is preferred, but since the first layer is for the ground, it should be something similar to the name. The class codes section should be only "2" selected or the code that represents the ground. Most LIDAR files have class code 2 = ground. For the "Return Values" section make sure to select all. Then have the Unflagged, synthetic points, model key-point, and overlap points checked (Use figure 12 and 13 to see the correct selections). Then hit run.

The second part will be doing the exact same process except this time looking to create the last return layer for the codes. Therefore, keeping the same input LASD file and then changing the Output name to something related to the last return. The "class codes" will select all. And the return values will be "Last Return", "Last of Many returns". This will depend on the data and the classification per LASD file. Then have the Unflagged, synthetic points, model key-point, and overlap points checked (Use figure 12 and 13 to see the correct selections). Then hit run.
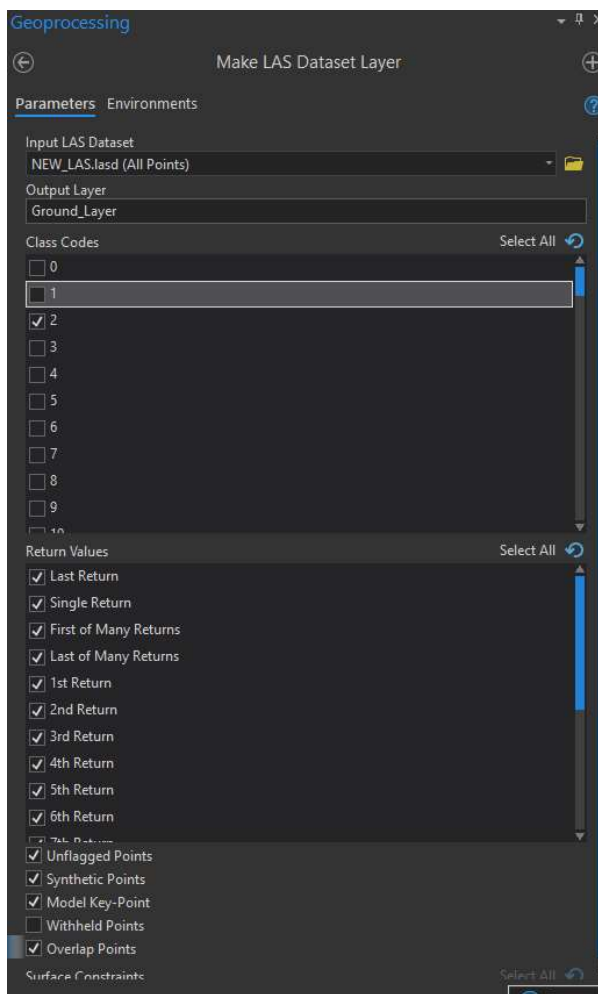

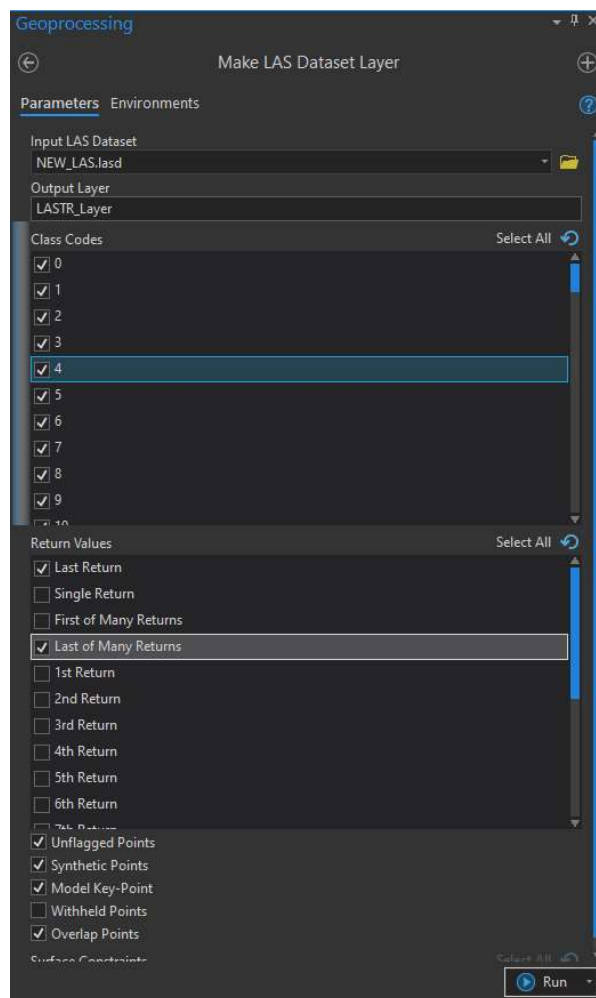*Figure 12. Ground layer created in Make LAS Dataset Layer tool*

Figure 13. Last Return Layer created in Make LAS Dataset Layer Tool

Step 5. *LAS Dataset to Raster*

This next section is very important because it takes the LASD point cloud and turns them into a raster which can show physical features like downed logs. Raster data can be manipulated into many different things using this tool below. This tool will be run twice to get a DEM and DSM

using the layers created in Step 4. The Ground layer will be used to create the DEM output
raster and the First Return layer will be used to create a DSM output.

First, you need to click again on the "View" tab and select "Geoprocessing" which is located in
the windows section. Then search for "LAS Dataset to Raster" in the toolbox. The first time
running the tool will be to get the DEM from the Ground Layer. Therefore, use the Ground layer
for the "Input LAS Dataset" dropdown. For the "Output Raster" dropdown put DEM_Raster. For
the "Value Field" dropdown select "elevation". For the interpolation Type put triangulation. For
the "Interpolation Method" put Linear. For the "Thinning Type" put "No thinning". For the
"Output data type" leave as a floating point. Leave the Sampling Size to cell size, and for the
sampling value put in the POINT SPACING which was the number from step 3. This point
spacing was .278 but round it down to .2 and leave the Z factor set to 1 (See Figure 14). Then hit
run.

Do the same thing for the second run of the tool but this time change the "Input LAS Dataset"
to the First Return layer created in step 4. Also change the "Output Raster" to DSM_Raster. Hit
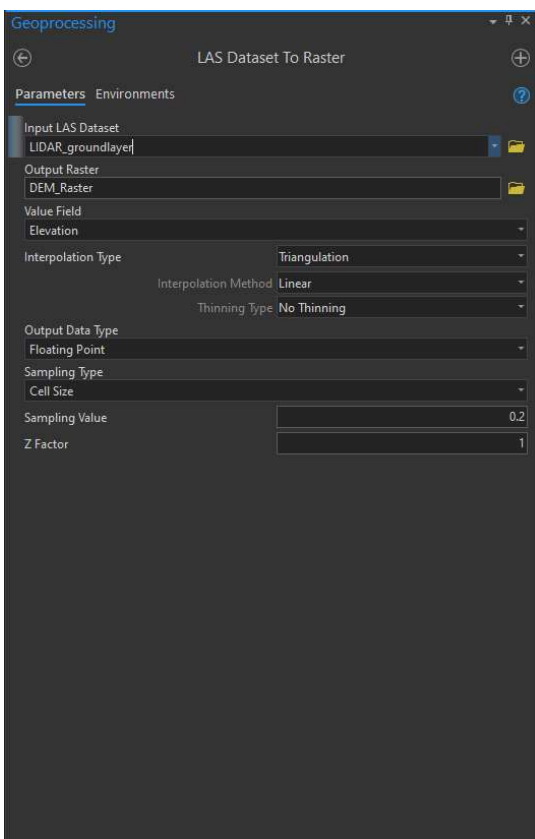run (See figure 15).
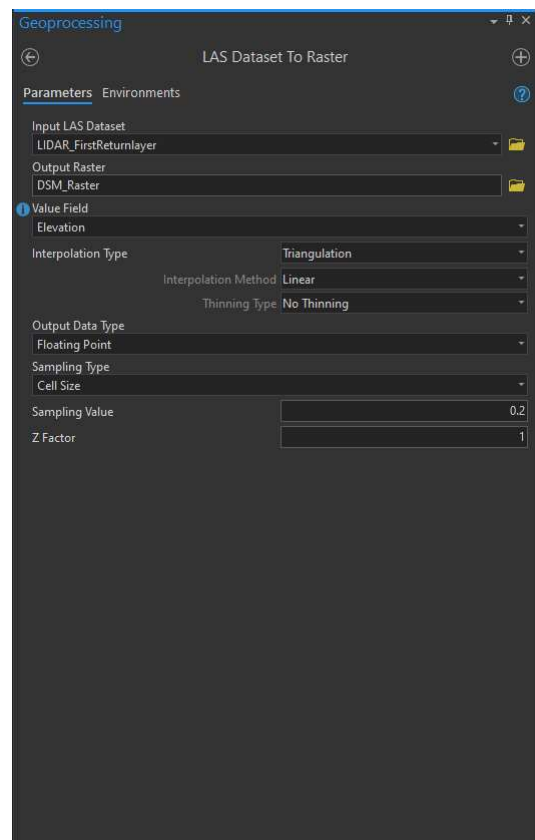

Figure 14. DEM created from Ground Layer

Figure 15. DSM Created from the First Return Layer

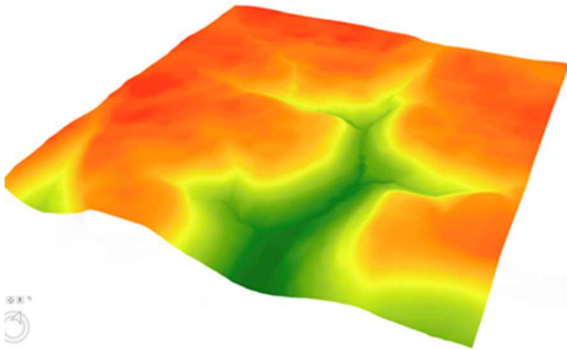The results of these Raster Tools will be below. (Figure 16 and 17)

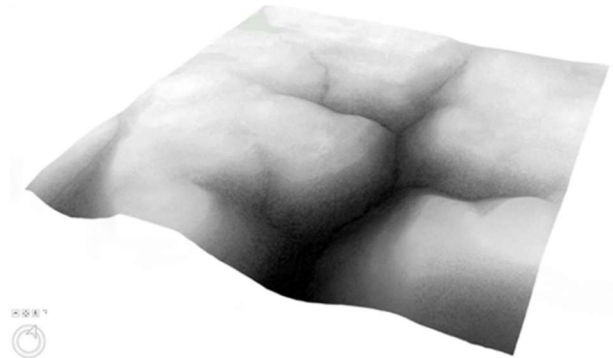*Figure 16. DEM Created from the Ground Layer*

Figure 17. DSM created from First Return Layer (In Intensity colors not Elevation colors)

Step 6. *Raster Functions*

The next step in the process is to take the DSM and DEM raster files that were created in step 5 and use raster functions in ArcGIS Pro to create a normalized Digital Surface Model (nDSM). This is done by using the "Minus Raster Function" to subtract the value of the second input raster from the value of the first input raster on a pixel-by-pixel basis. An nDSM represents the height of features above ground, rather than the elevation of features relative to mean sea level, or an ellipsoid. These relative height values are essential for estimating vegetation height.

First navigate to the "Analysis" Tab and locate the "Raster" section. Then click on the "Raster Functions Icon". Search "Minus" in the menu and click on it. For the "Raster" select the DSM file. For the "Raster2" select the DEM (See Figure 18). The next step is to stay in the raster functions menu and search "Hillshade" Click on the raster function icon and fill out the tool dropdown options. For the "Input" put in the nDSM that was just created by the using the minus tool. Leave all the other options default (Figure 19). Hit run. The results should look almost moonlike. This allows the features to stand out more that are in the nDSM.
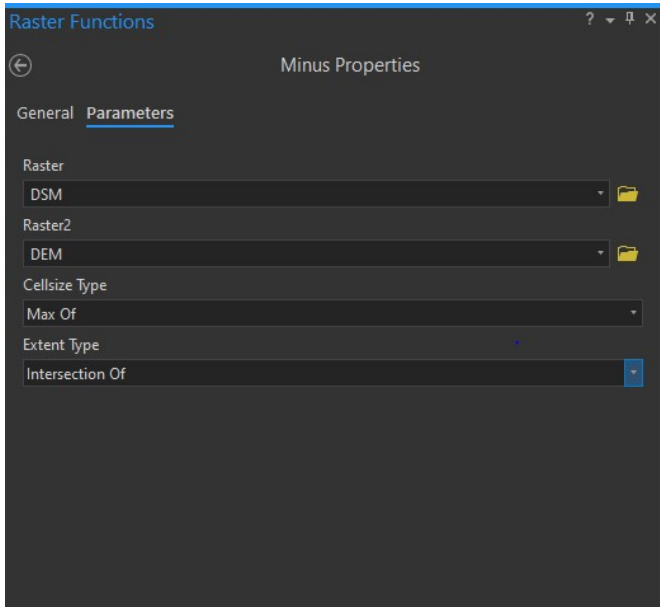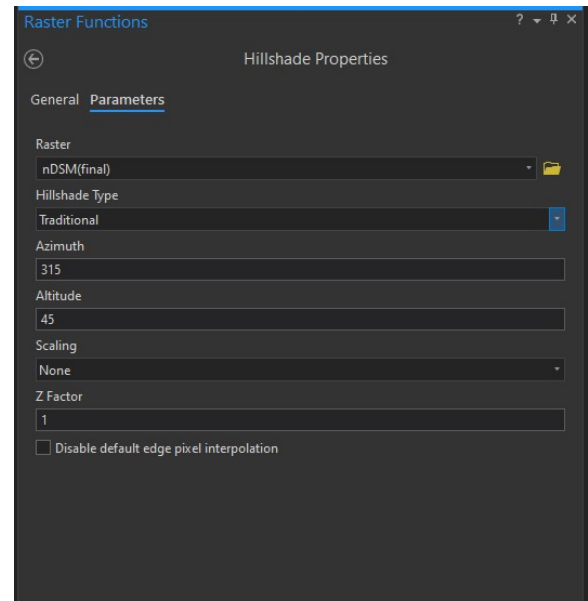
Figure 18. Minus Function for nDSM Creation

Figure 19. Hillshade Raster Function

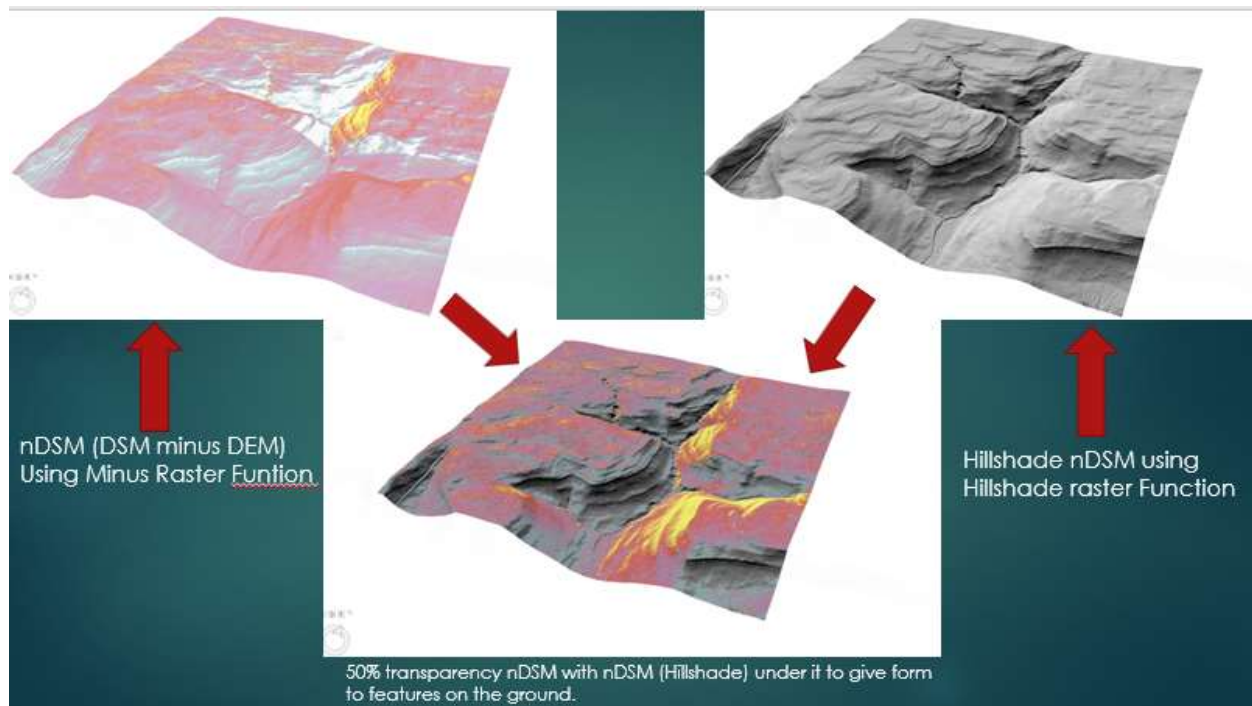Result below (Figure 20) is when combining both nDSM and Hillshade maps.

nDSM (DSM minus DEM) Using Minus Raster Funtion.

Hillshade nDSM using Hillshade raster Function

50% transparency nDSM with nDSM (Hillshade) under it to give form to features on the ground.

Figure 20. Result of nDSM and Hill shade combination.

Results

The results from this process clearly show the downed logs and undergrowth on the forest floor. This data did not have any analysis performed on it. This is left to the user. There are many ways to conduct analysis on the multiple data layers. The final results have a color scheme that shows elevation. The undergrowth and logs are dark pink ,orange, and red. While the ground is lighter pink. There are other colors that can be used. The hardest thing when doing further analysis is distinguishing between the logs and undergrowth that are same color as the ground.
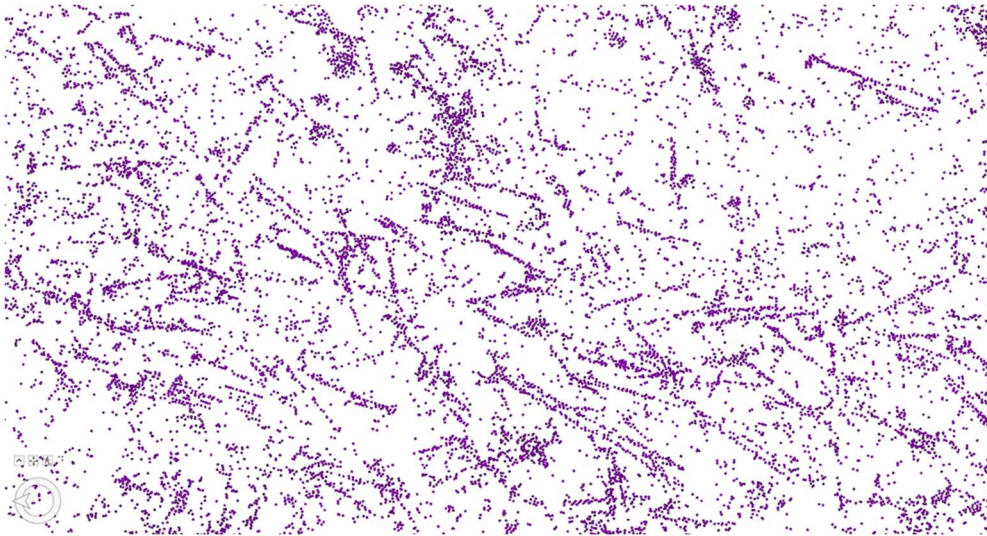

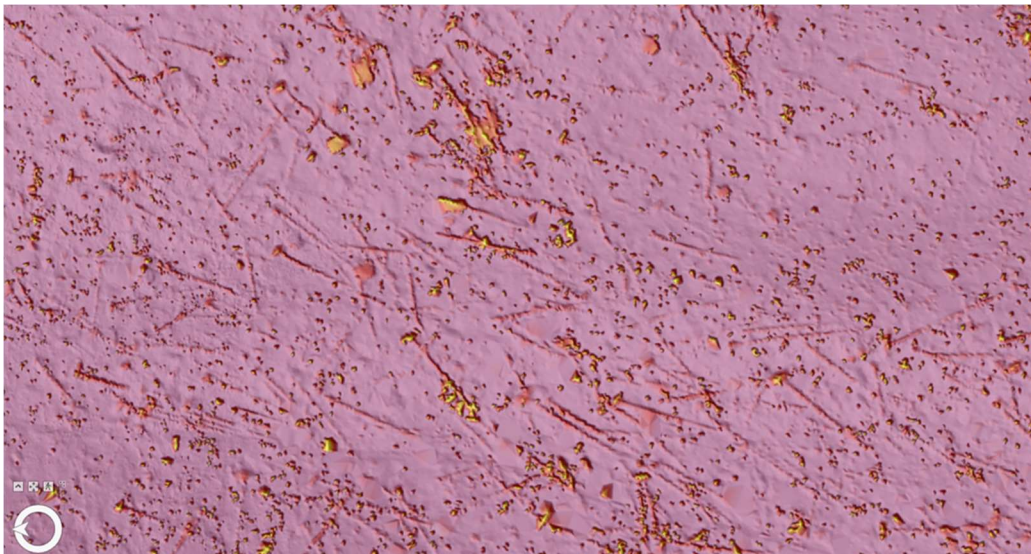*Figure 21. Before of the raw LIDAR points*

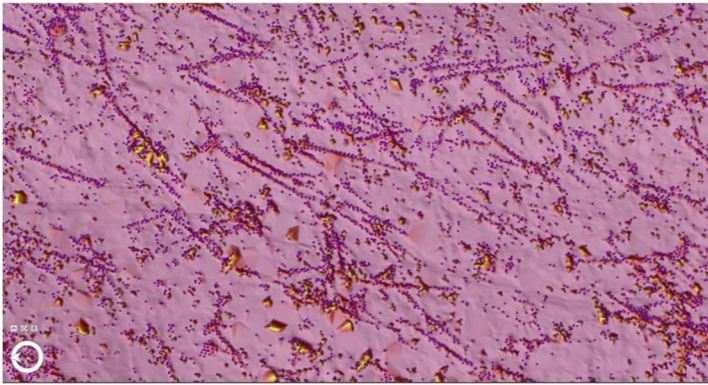*Figure 22. After Results of the Raster data processed with the Hillside and nDSM.*

Figure 23. RAW LIDAR points overlaid on Raster.
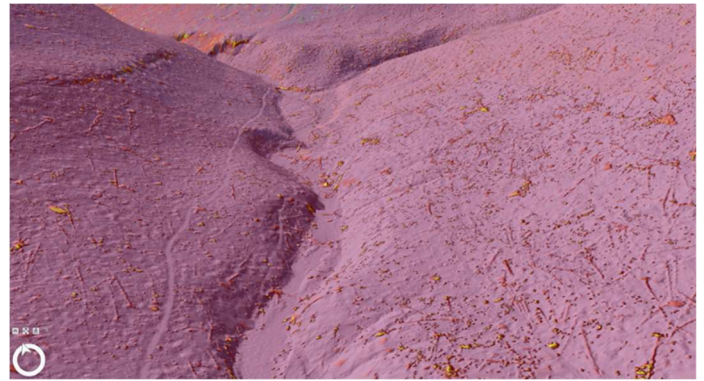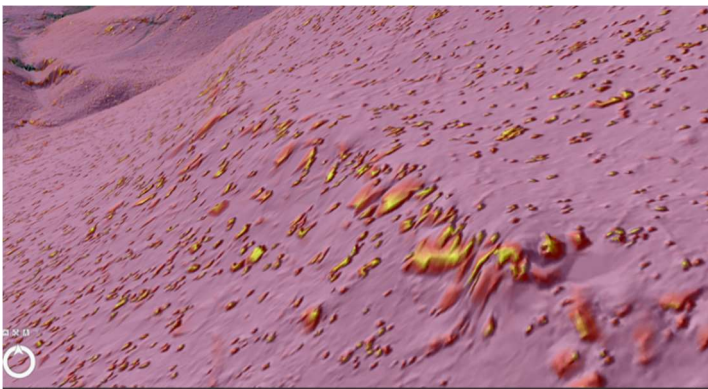

Figure 24. Valley 3D view of LIDAR downed logs

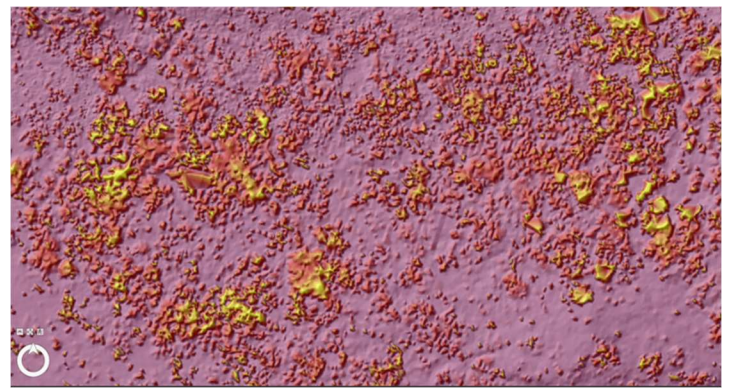*Figure 25. Rocks are part of the undergrowth*

Figure 26. Large Amounts of Undergrowth on the forest floor

Conclusion

Ricketts Glen state park has a large amount of undergrowth, there are a lot of rocks which is the problem. With this 2017 data taken from an airplane it is hard to differentiate rocks from shrubs and know more details of the ground. Many of the downed logs are in the valley on slopes and this is likely due to erosion or other wash outs. The hot spots of the classified LIDAR data are in the East side of the valley. LIDAR is a very good technology to use for forest management and locating downed logs on the forest floor. It gives the ability to fly large scale projects in a short amount of time vs working with ground teams which would be very time consuming. With better data and a better sensor, the results will be much better, however this 2017 USGS data used from PASDA.com was quick and easy to use as an example. Soon, LIDAR will be the best way to map and navigate large scale areas for forest management.

Resources

https://www.pasda.psu.edu/

https://www.youtube.com/watch?v=L4tVXARSrUo&t=501s