A preliminary guide for working with LiDAR data.
Moine Mhor Case study.

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Introduction

The advantages in Remote Sensing have been elevated to a new level with the more frequent deployment of airborne LiDAR (Light detection and ranging, a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth). Has made the access to LiDAR data easy and cost saving resulting in an abundance of available data that have the potential to generate maps that will facilitate in numerous ways nature conservation and ecology.

However, this availability of LiDAR data, creates the challenge for organisations that have not previously used LiDAR data of how to handle such data without reverting to external contractors that can have a considerable cost.

In this document, I present a pipeline for handing LiDAR data (las/laz) files using open-source software and plug-ins which can produce preliminary data from LiDAR data and help make initial decisions for conservation. A case study will be also presented for identifying Peat condition in Moine Mhor.

Part 1. Producing initial maps from Las/laz files in QGIS

QGIS (Quantum GIS) is a geographic information system that is opensource available for free for all users. Its quickly becoming the GIS of choice for many organisations because of its versatile with other platforms (python, PostgreSQL, and others). In addition, its opensource nature allows developers to produce algorithms that can serve specific needs of GIS professionals and organisations. Recently QGIS (QGIS 3.34) has added the ability to process LiDAR data (las/laz) which previously was only available via special software that comes with considerable cost. QGIS is available for download here https://qgis.org/en/site/ and it is compatible with several Operating Systems including Windows, MacOS and Linux.

1.1 Loading Las/Laz files into QGIS 3.34

After downloading and installing QGIS 3.34, and launching it, it is possible to directly load the Las/laz files to its main interface. (Figure 1)

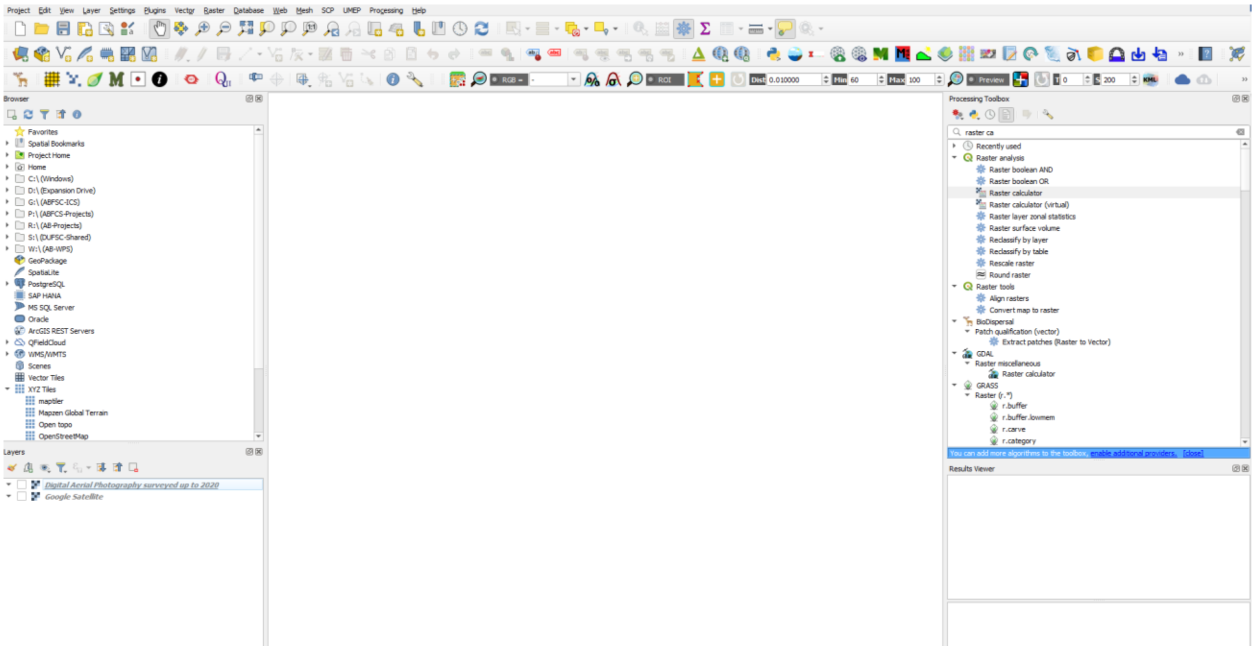


Figure 1. The Main QGIS 3.34 interface

The newest version of QGIS allows to directly load Laz/Las files. The LAS (LIDAR Aerial Survey) file format is a widely used binary file format designed to store 3D point cloud data collected by LiDAR (Light Detection and Ranging) surveying systems. It was developed by the American Society for Photogrammetry and Remote Sensing (ASPRS) in 2003 and is now considered the industry standard. The LAZ (LASzip) file format is a compressed version of the LAS (LIDAR Aerial Survey) file format used for storing LiDAR data. It was developed in 2007 as an open-source software solution to reduce the file size of LAS files. By opening the **Data source Manager** user can load laz/las files by selecting the point cloud data from the menu as shown below in Figure 2.

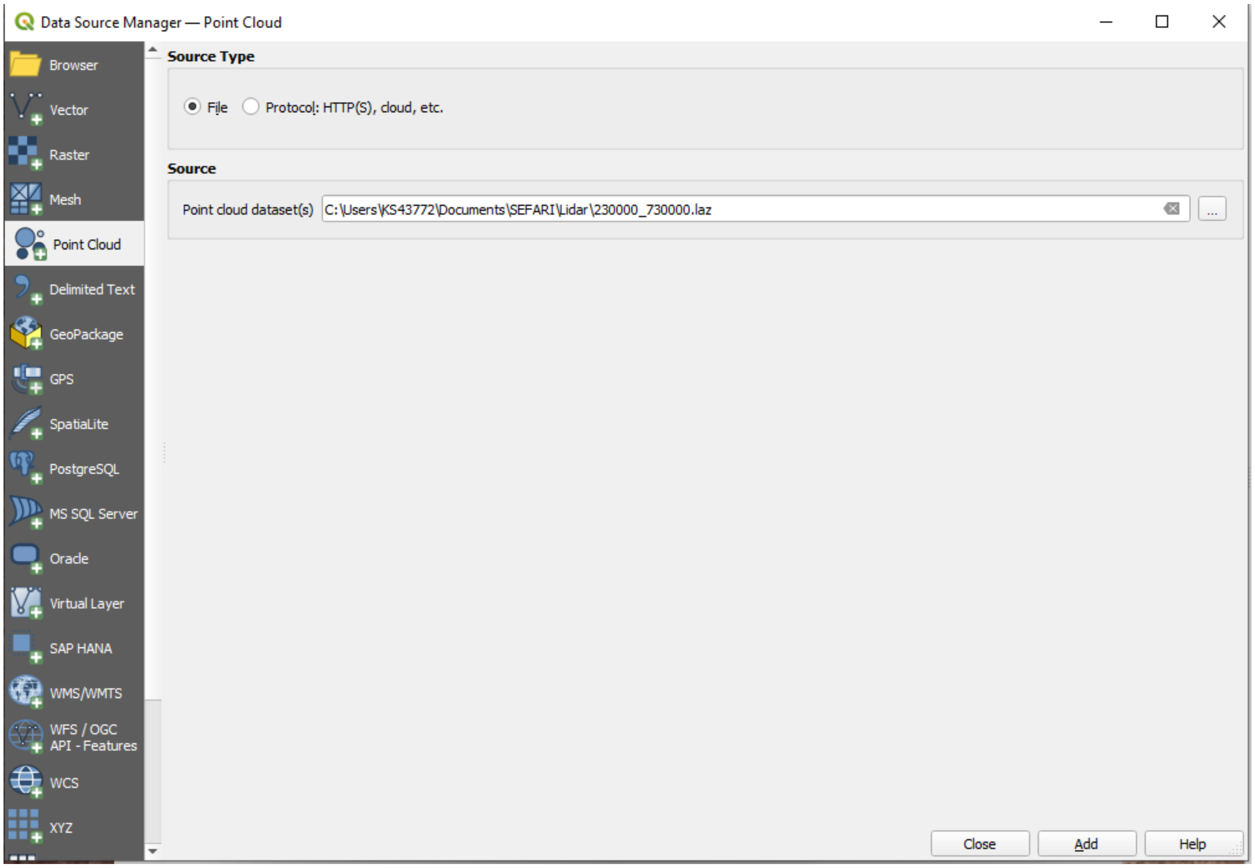


Figure 2. Loading a laz/las file to QGIs via the Data source Manager

To continue at this point, some plug-ins must be downloaded to QGIS to perform some of the steps below. These are:

- Qgis2threejs
- Relief Visualization Toolbox
- OPEN LIDAR TOOLBOX
- LAStools

1.2 Classifying a laz point cloud file.

On many occasions the laz Lidar files will come in an unfiltered format which means that the points have not been classified depending on their corresponding returns. In the figure below is an unclassified laz file.

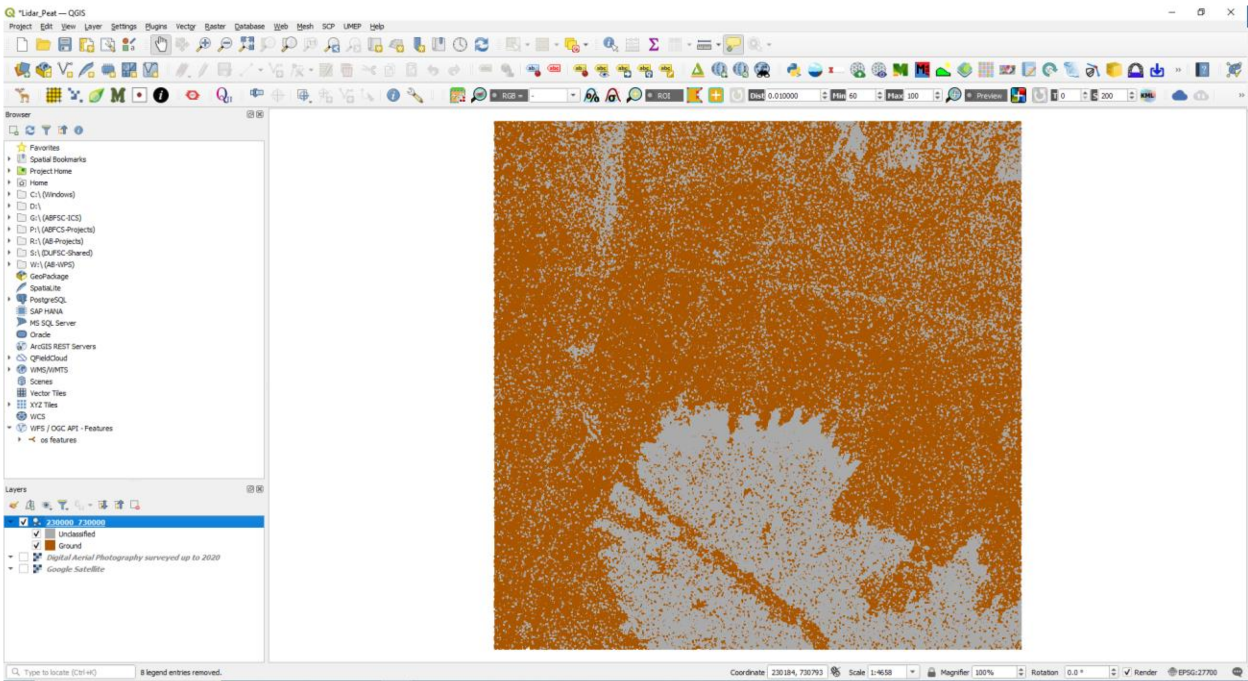


Figure 3. The imported las file in QGIS.

In this instance there is also the possibility that the Laz file is not projected to a specific Coordinate Reference System (CRS). It is possible to assign a projection to the laz file using the algorithms that come with QGIS 3.34.

To assign a projection, use the “Assign projection” tool from the processing toolbox of QGIS.

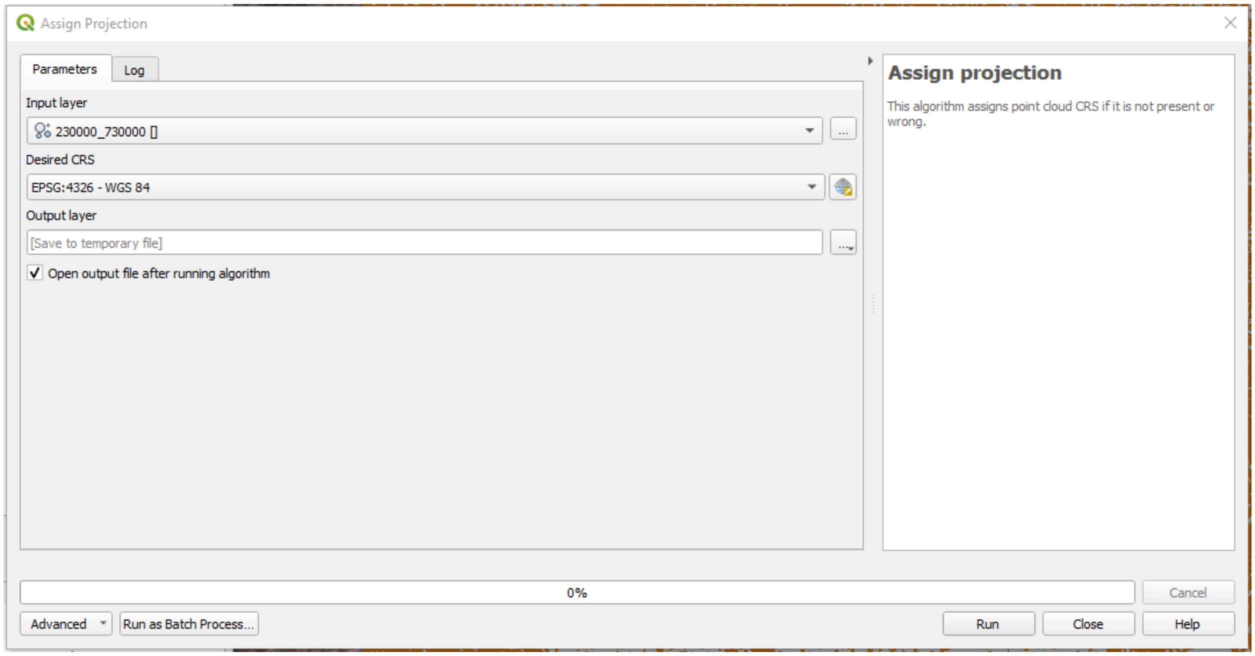


Figure 4. Assign projection to las algorithm.

When the tool interface opens, is it possible to insert the desired laz files in the Input layer option. Then selecting the desired CRS, and finally the location where the new laz file with the assigned CRS will be stored.

After the las file has been assigned to a CRS, it can be classified to view the different features identified by the LiDAR. This can be done by using either the Classify LAS/LAZ tool available with the Open LiDAR Toolbox plug-in or the Lastools lasclassify. It must be noted that both tools produce the same result, the Lastools algorithm is only available for a trial period as the toolbox requires a paid licence to fully make it operable.

On the other hand, the Open LiDAR toolbox uses the same algorithms as Lastools, but it is open source.

In this example we use the Open LiDAR Toolbox plug-in as it is simpler to use and open source. After selecting the "Classify LAS/LAZ" tool from the Processing toolbox list, the interface looks like the figure below.

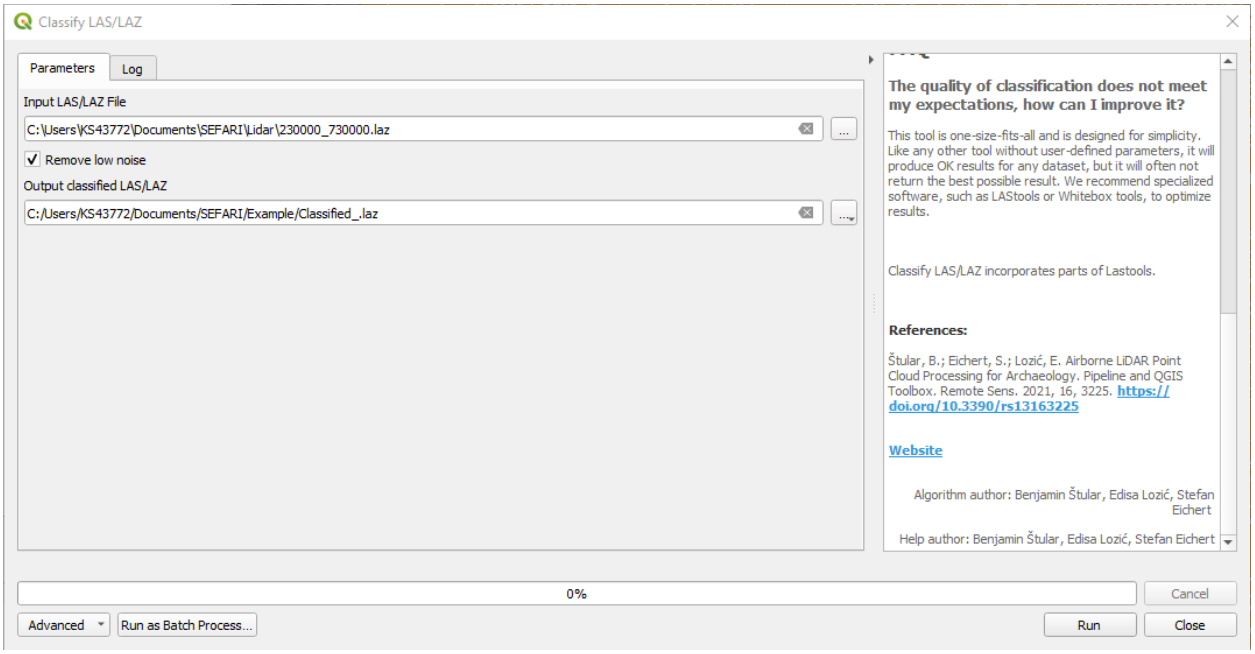


Figure 5. Classify las algorithm.

In the tool interface the LAS/LAZ file to be classified can be selected and the space where the output classified Output LAS/LAZ files can be stored. In addition, the Remove low noise box should be checked. This option is a good practice since it allows the tool to remove unclassified low noise that causes sharp holes in the classified Laz file where there are no classifications. There is also the possibility to change some of the algorithm settings by selecting the advanced button on the lower left of the interface and then selecting "algorithm settings." A new tab with further options will appear. Here we can select the distance units and areas units that the algorithm will use as well as some performance options.

After the tool completes the classification a new laz file will be produced that will have the features that were identified by the LiDAR.

1.3 Visualizing in 3D Las/Laz files in QGIS 3.34

At this point it is possible to use the 3D view tool of QGIS 3 to view a 3d representation of the Lidar file and can get some first conclusions. The 3D view can be accessed from the main menu bar of QGIS by selecting View 3D map New 3D map view. The tool will automatically visualise the classified laz file in a 3D map.

In the resulting 3D map view it is already possible to view the features of the terrain and vegetation such as individual trees. It is worth noting that the more detailed is the original laz file, in terms of point per square meter the more detailed the 3D view will be but the longer it will take for the 3D view to render.

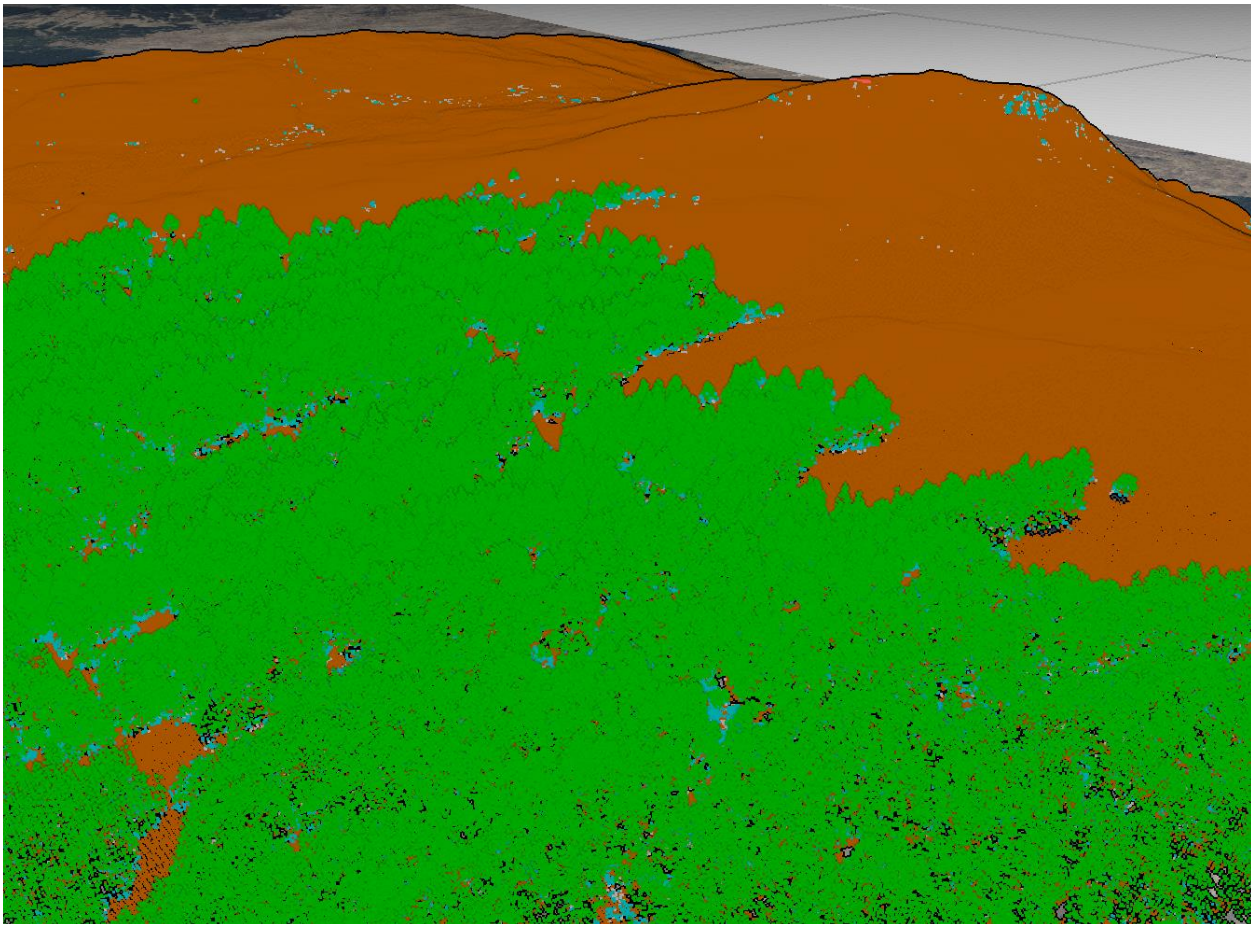


Figure 6. 3D visualisation of the classified las.

1.4 Creating and visualizing in 3D DSM and DTM files in QGIS 3.34

At this point, it is possible to convert the classified laz file to either a Digital Surface Model (DSM) or a Digital Terrain Model (DTM). This will convert the las file to a raster tiff file. This can be done using QGIS point cloud conversion tools, available in the processing toolbox. The tool that is used for this is the export to raster tool.

In this tool, as input the classified las/laz file is used. The attribute menu is needed to define which attribute from the laz file will be used to calculate the values of the pixels in the generated raster. For this from the drop-down menu the Z value will be used to store the height values of the laz file to the raster file. If the rest of the choices are left in default the raster file that will be produced is a DSM as it will store the values of all the features of the point cloud (ground, vegetation, building etc). In addition, the toolbox offers a similar tool that uses triangulation for the calculation of the raster that produces more accurate results. Both tools have similar interfaces.

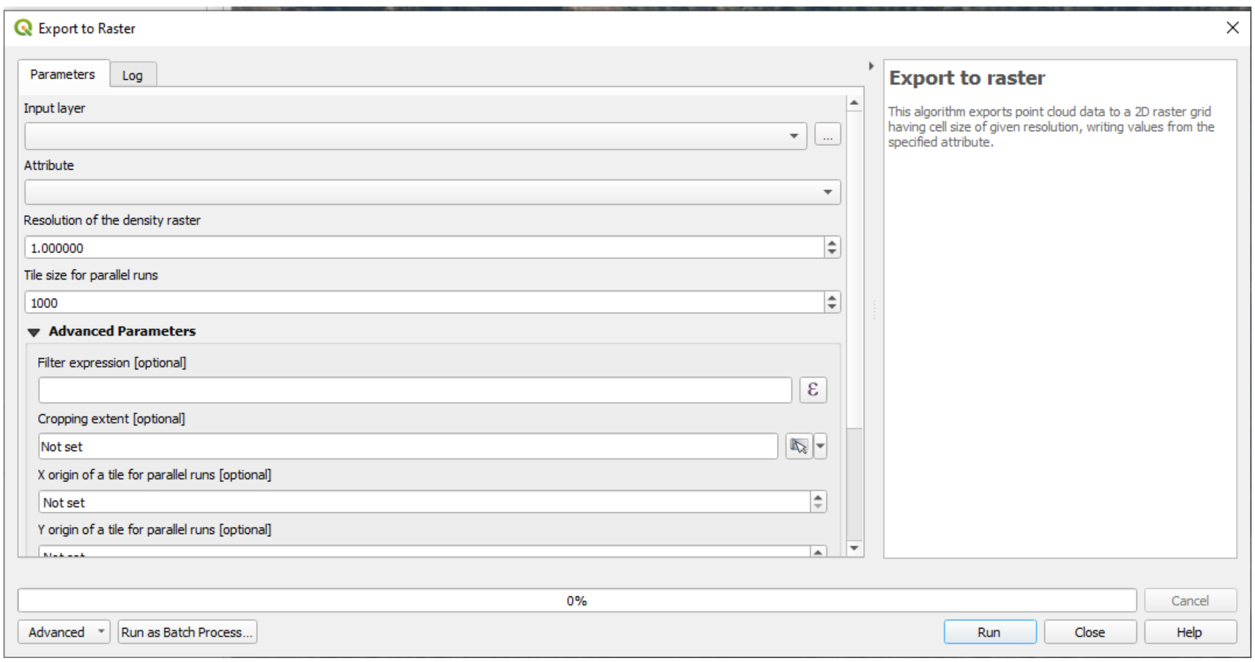


Figure 7. Export to raster algorithm.

As with the point cloud the DSM raster can also be viewed in a 3D mode to better understand the features of the DSM. This can be done again using the 3D view of QGIS as described previously or it is possible to use the QGIS2Threejs plug-in. This is available from the main menu of QGIS and by selecting Web then QGIS2Threejs. This will open a new window where the DSM can be selected and the plug in will render it in 3D. An advantage of this plug-in is that it can render the DSM with any of the active layers on QGIS map canvas. This can prove useful as it allows to depict RGB photos of the area of the point cloud to gain more information.

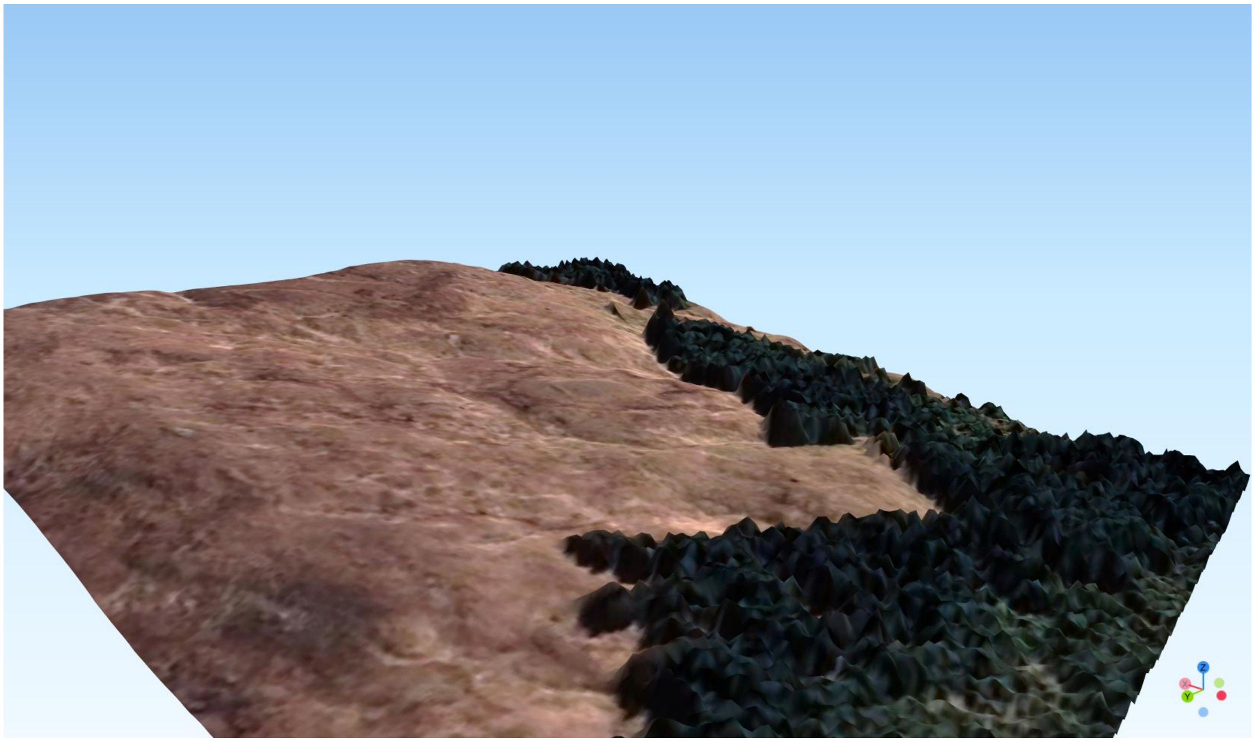


Figure 8. 3D Visualisation with aerophotography.

To create a DTM (Digital Terrain Model) the same tool from QGIS point cloud tools can be used. (Export to raster). However, to correctly produce the DTM some changes in the algorithm tool must be considered. In the export to raster tool interface (or Export to Raster Using Triangulation), after choosing the classified las/laz file and the attribute, then in the advanced Parameters section, the ε button must be selected. This will bring up a new window that will allow to select which of the attributes of the classified laz/laz file will be exported to a raster. For the DTM to be exported, from the Laz/Laz file's attributes the classification attribute is selected and from values the value 2 which represents the ground is filtered. This will allow only the point cloud points that have been classified as ground will be exported so a "clear" DTM will be produced without the other features considered. Below in the figure is the filter expression for the export of the DTM.

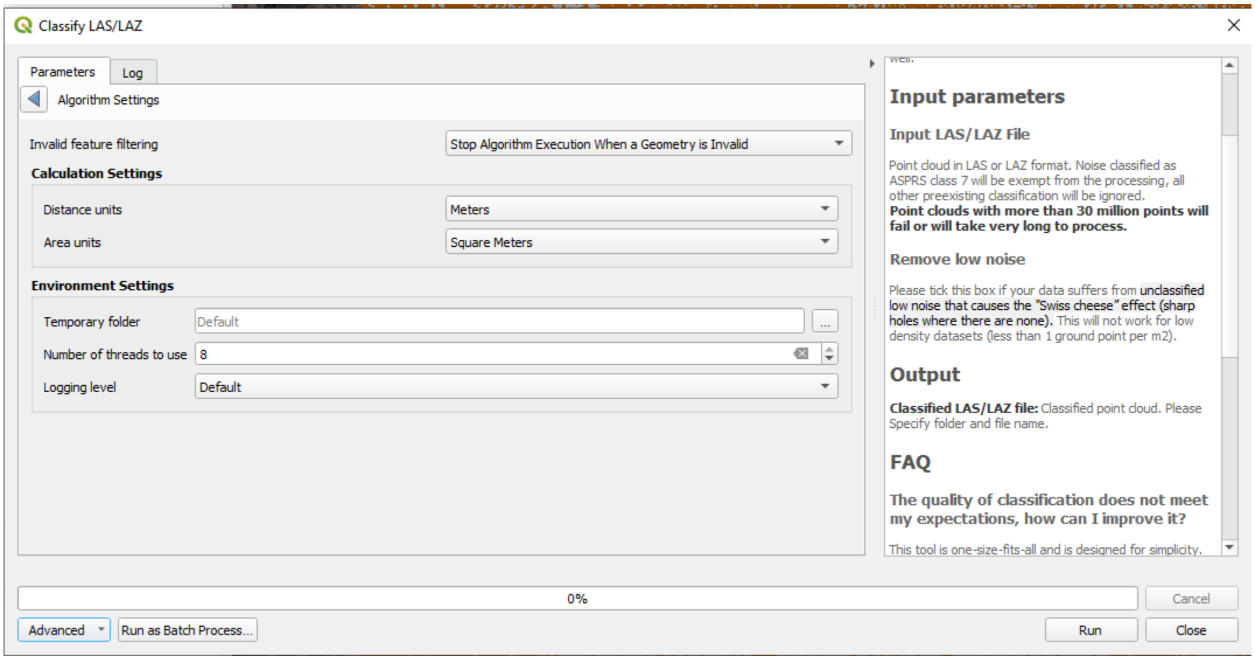


Figure 9. Creation of a DTM.

After the tool has finished, the exported DTM can be again viewed either using QGIS 3D view or the QGIS2threejs plug-in. However, at this point for the DTM a better view of the DTM can be achieved by calculating a Hillshade raster from the DTM. This can be achieved either using the Hillshade algorithm that QGIS has or using the **Relief Visualization Toolbox** plug-in that offer various algorithms that enable the production of several types of topographical relief mapping. One of those is the multidirectional hill shading algorithm that allows the production of a Hillshade raster illuminated from several different angles giving a more detailed view of the ground features.

As an example, the multidirectional hill shading algorithm of the Relief Visualization Toolbox will be used to demonstrate the detail of the produce relief raster.

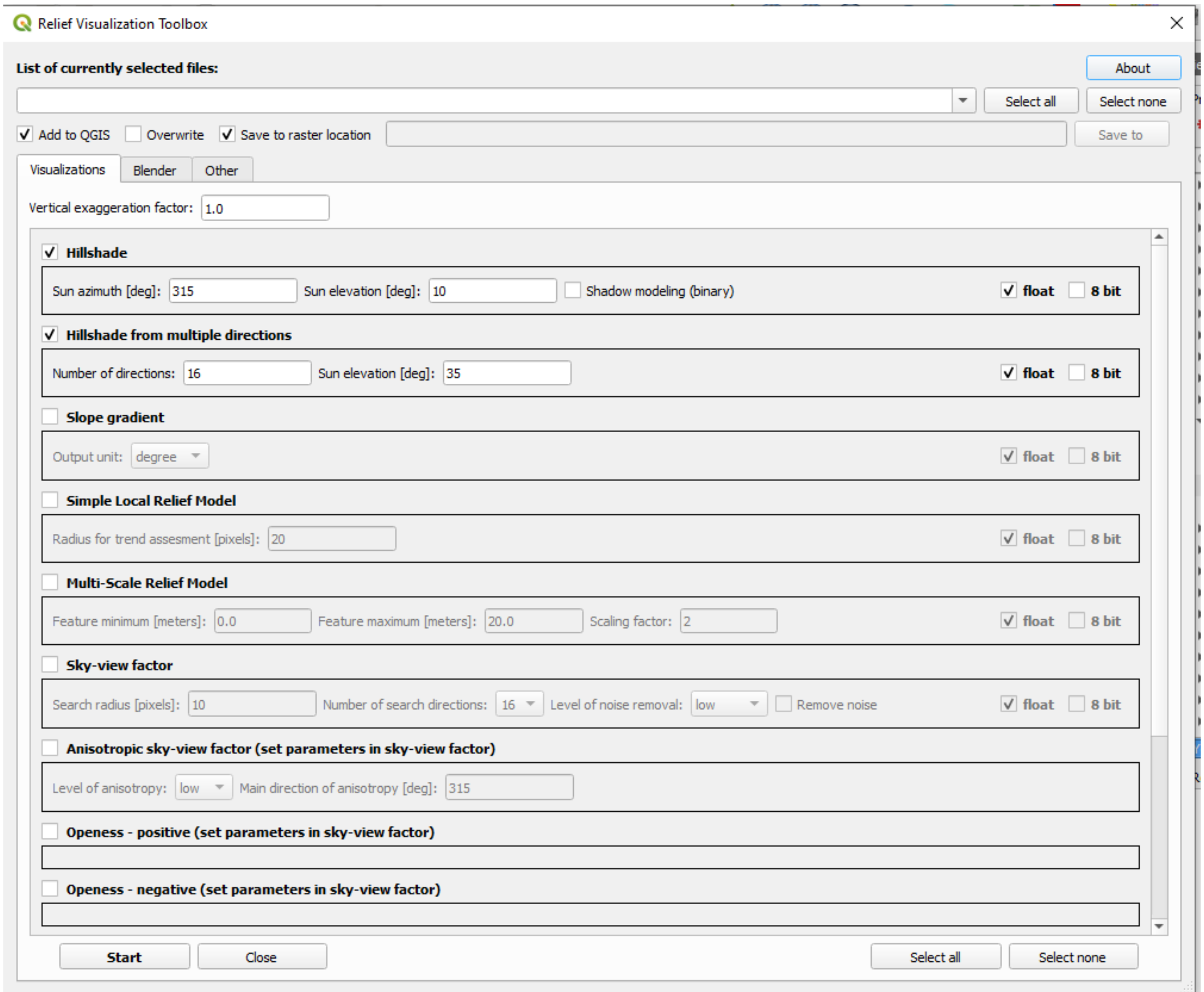


Figure 10. Relief Visualisation Toolbox interface.

From the RVT interface the DTM can be selected and then the folder where the resulting rasters will be stored. After selecting the "Hillshade" and "Hillshade from multiple directions," then start button is selected. In the figure below the difference between a simple Hillshade and a multidirectional hillside is shown.

Figure 11. Hillshade generated form the DTM.

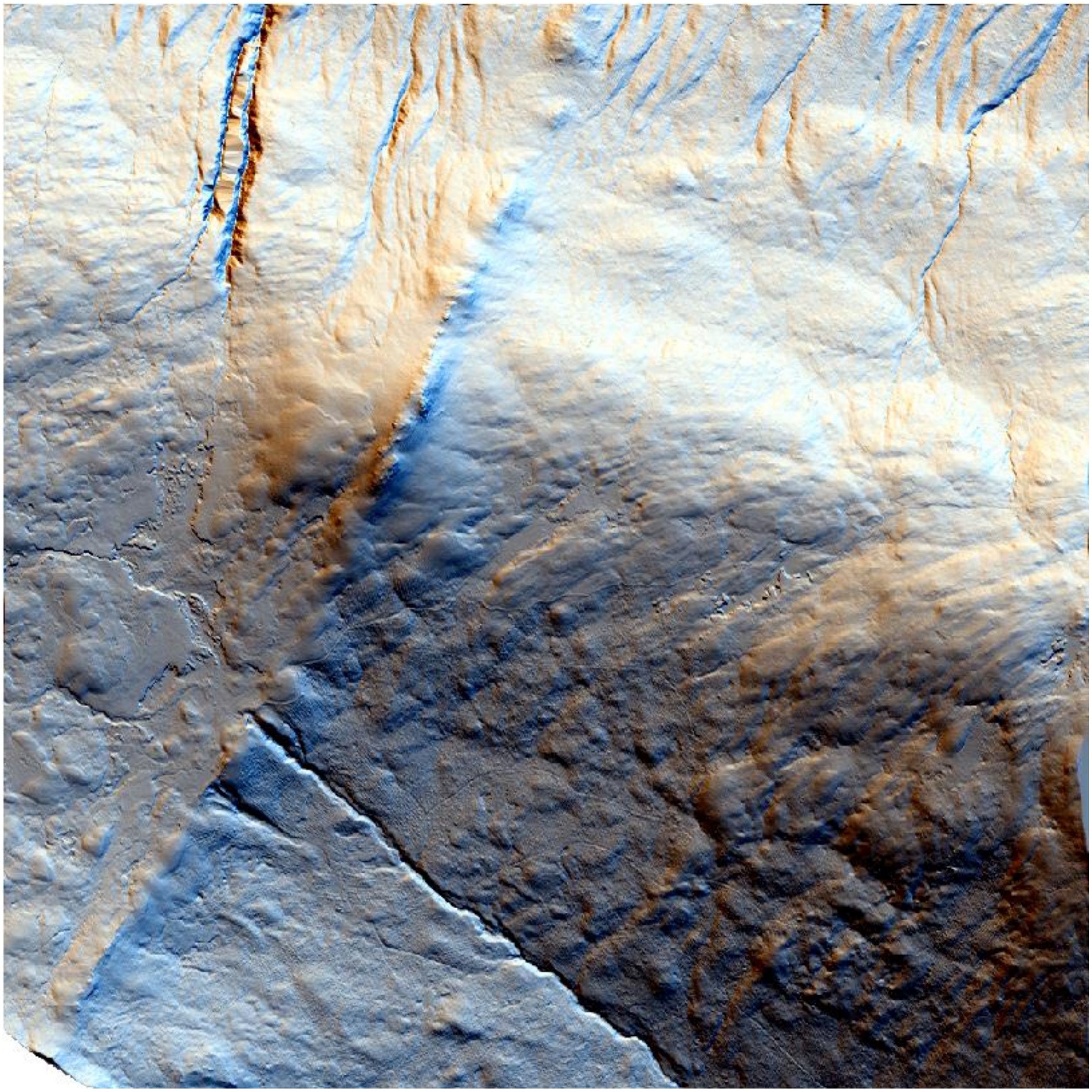


Figure 12. Multidirectional Hillshade generated from the Relief Visualization Toolbox.

Part 2. Moine Morr Nature Reserve Case study

To better demonstrate the usefulness of point cloud data, in detecting changes in the landscape and how this can affect decision making in the context of nature conservation, a case study of detecting drainage in peat areas was selected. Peat degradation and peat restoration is a major initiative across Scotland and access to better data to detect and analyse peat habitats is important. LiDAR derived data and maps can contribute massively to the analysis of Peat habitats.

Moine Morr Nature Reserve was selected for this case study as Forestry and Land Scotland conducted an aerial LiDAR scanning of their assets in Western Scotland in 2022 and one of the areas that was covered was the Moine Morr Nature Reserve. This provided the opportunity to generated LiDAR related data, from a recent survey with a high points of scanning per square meter.

Methodology

The main goal of the case study was to demonstrate how a detailed DEM derived from point cloud data, can assist in the detection of drainage canals in a peat habitat compared to other methods that include derivatives from habitat data or machine learning from satellite imagery. Also, a method of calculating the volume of peat extraction from peat habitats will be demonstrated as it is an important metric that can be easily derived from point cloud derivatives. All the tools used are the same that were described in the first part of the document that come with QGIS3. Below is a map of the study area.

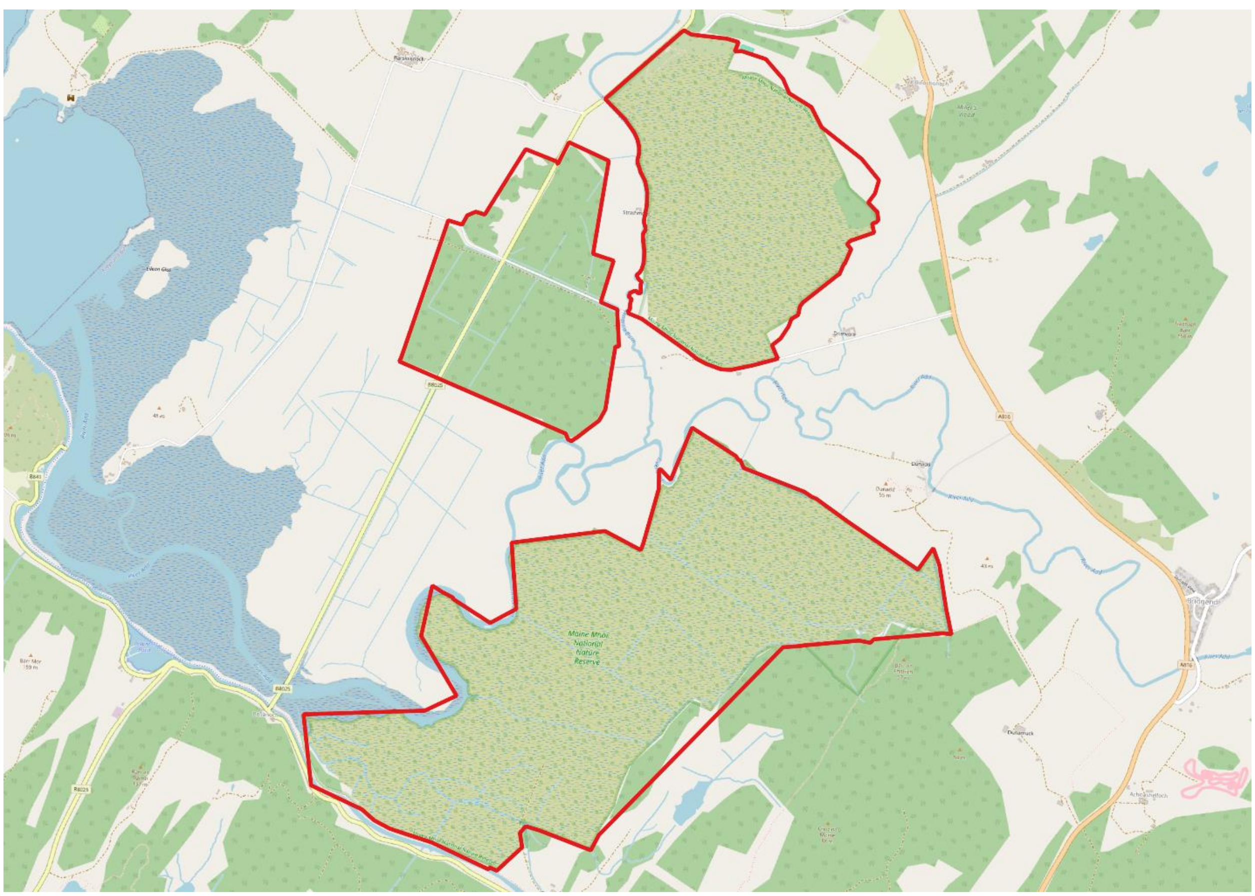


Figure 13. the location and boundaries of the Moine Morr reserve.

The first step was to load and merge all the point cloud files that cover the area of the reserve. The merge of all the point cloud files was achieved using the QGIS tool Merge, from the Point cloud data management toolbox. The next step after margining was to classify the point cloud data as the data provided by Forestry and Land Scotland were not classified. As mentioned in the first part the tool for classification that was used was the Classify algorithm from the Open LiDAR Toolbox.

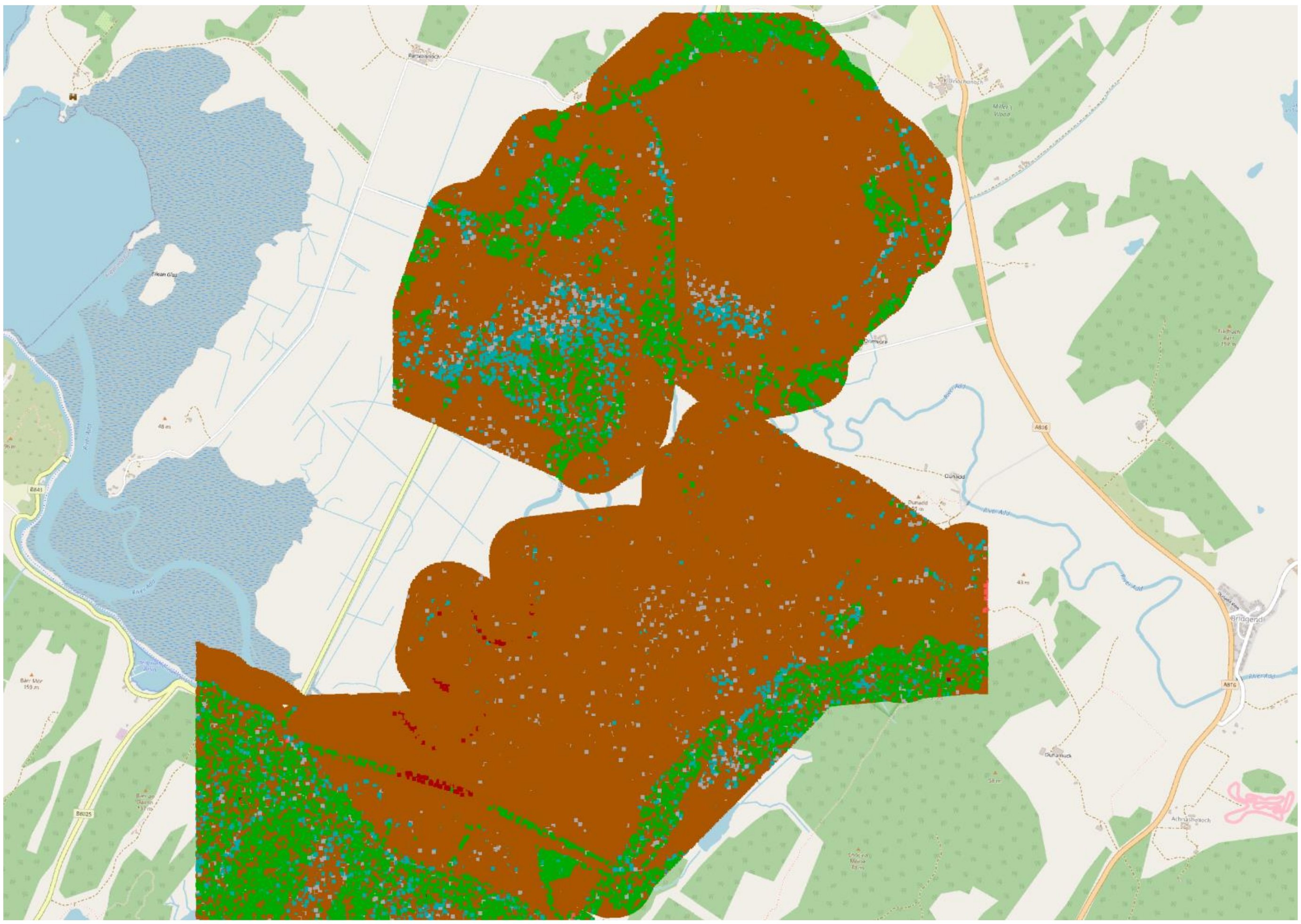


Figure 14. Lidar coverage of the Moine Morr Reserve.

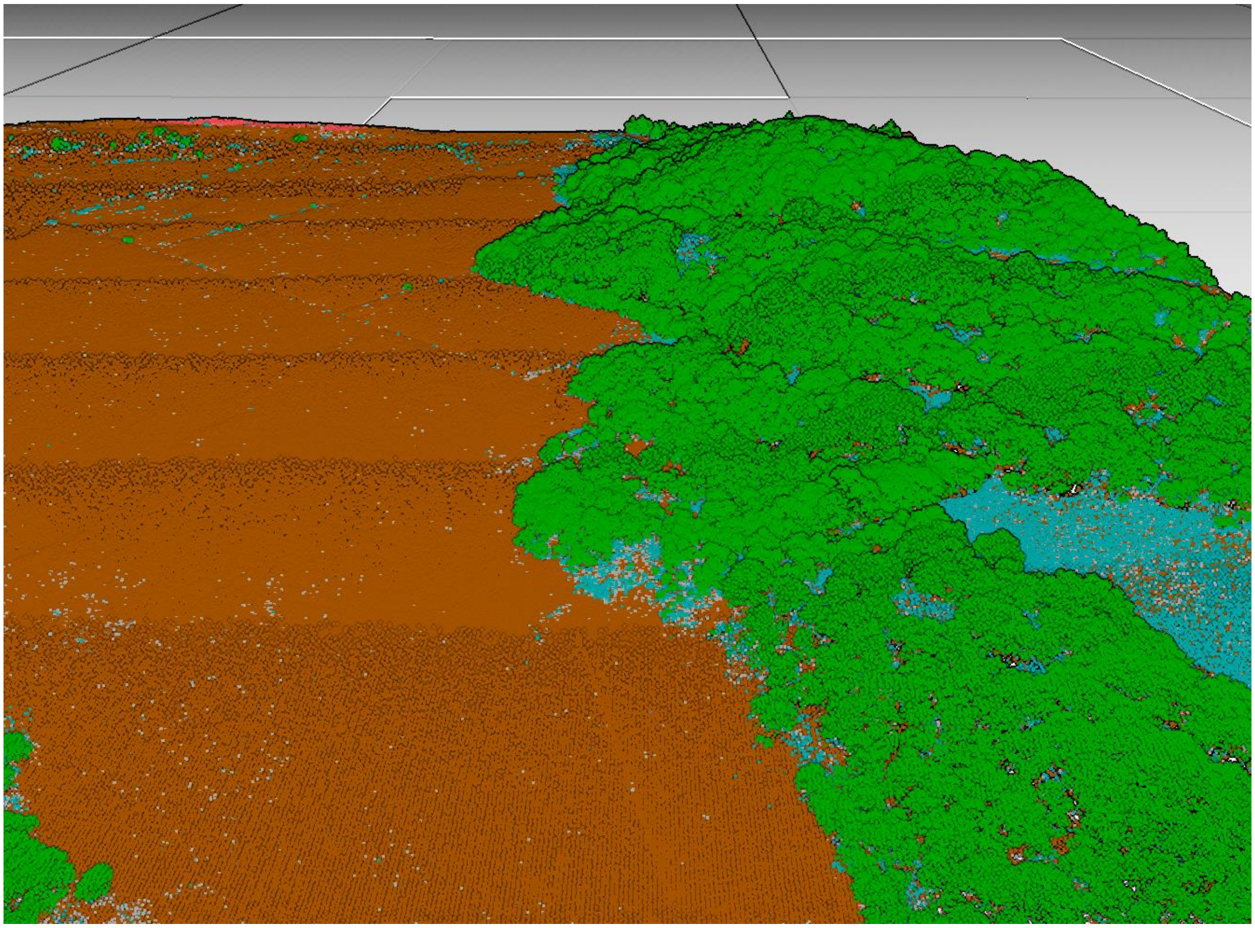


Figure 15. 3D Visualisation of the Lidar scan of the reserve.

After the classification, the level of detail across the reserve area is already observable with trees, bushes, and other vegetation clearly visible.

The next step was the creation of a Digital Elevation Model (DEM), which would be the main data source for the analysis.

The tool used for creating the DEM was the export to raster tool from QGIS Point Cloud Conversion toolbox, and as described in the first part only the ground points of the point cloud were used to produce the DEM.

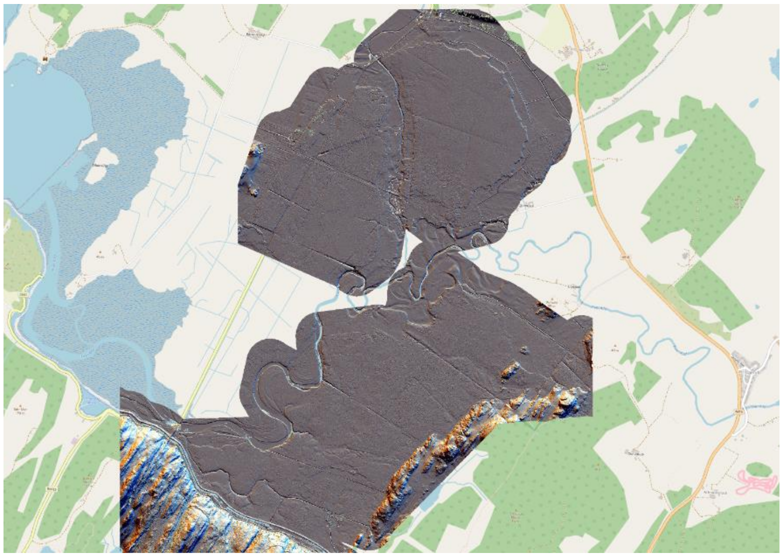


Figure 16. DTM of the reserve.

After the DEM was produced the next step involved the creation of a Hillshade model that will better demonstrate the existence of drainage canals and ditches in the reserve. For this, the Relief Visualization Toolbox was used, which provides the opportunity to create a Hillshade that uses lights position (theoretical sun position) from several distinct positions highlighting the features of the landscape better than a traditional Hillshade model.

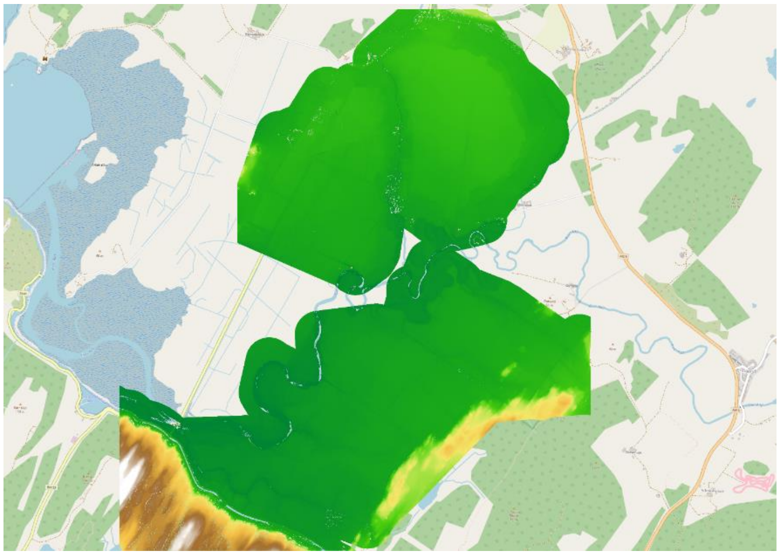


Figure 17. Multidirectional Hillshade of the reserve.

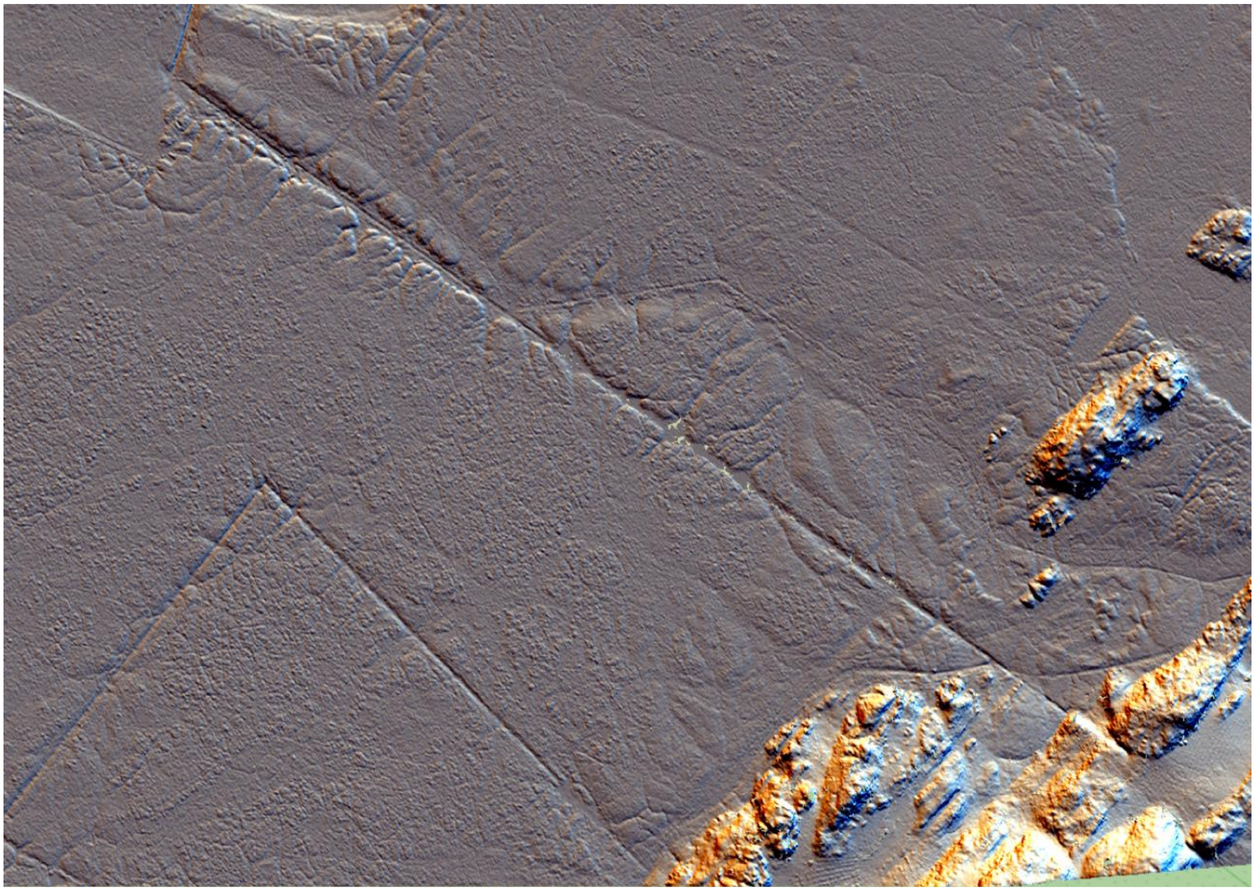


Figure 18. Detailed view of drainage canals on Peat

At this point with the production of the Hillshade some of the landscape features can already be distinguished and especially potential drainage features can be identified by just viewing.

However, a lot of other useful datasets can be produced at this points that are useful in determining drainage features. A good indicator for determining drainage and the stability of the peat habitat is calculating the Slope angles of the area. According to

"*Mills, A.J. and Rushton, D. 2023. A risk-based approach to peatland restoration and peat instability. NatureScot Research Report 1259*"

the following table provides the slope angles and their significance in peat stability and condition.

Slope range (°)	Significance	Score (Peat Slide)	Score (Bog Burst)
>15	Failure typically occurs as peaty-debris slides or peat slides, although to a lesser extent than on gentler slopes, bog bursts rarely occur	3	1
7.5 - 10.0	A frequently reported slope range for peat slides, bog bursts sometimes occur in this slope range	3	1
5.0 – 7.5	A frequently reported slope range for peat slides, bog bursts are also reasonably common in this slope range	3	2
0 - 5.0	The most frequently reported slope range for bog bursts, though peat slides may still occur	1	3

Table 1. Peat stability on slope range

Based on this table, the Slope of the study area was calculated using the DTM as an input and using the Slope algorithm provided within QGIS. The resulting map depicts the slope of the area in degrees. In the following map the areas that have the highest slope within the bog can be seen and they clearly coincide with drainage ditches.

In addition to the previous map, where the Slope in degrees can highlight areas where most of the drainage may occur, QGIS3.34 has a useful tool for viewing the profile of a specific area, and in this case the depth of a drainage canal which in combination with the slope gradient can provide useful information for the peat condition. Below is an example in one of the drainage canals.

In the map provided the profile view is being conducted along the green line shown in the map with a direction from South to North.

In the produced profile view graph produce by the Profile view tool, it is clearly visible a sudden drop in depth of around 1.2 meters 60 meters from the start of the line.(Green line in the map below) This drop in depth coincides with the presence of the drainage canal that can be clearly seen in the Hillshade but also can be detected in high degrees if Slope in the Slope map. This kind of information are extracted by the values of DTM but also can be extracted directly from the point cloud. With a more detailed points cloud (more points scan per square meter, the current on is about 15 points per square meter) the resulting profile view will even more detailed providing a detailed view of the landscape which can help detect drainage canals that with ither methods would not be able to be detected.

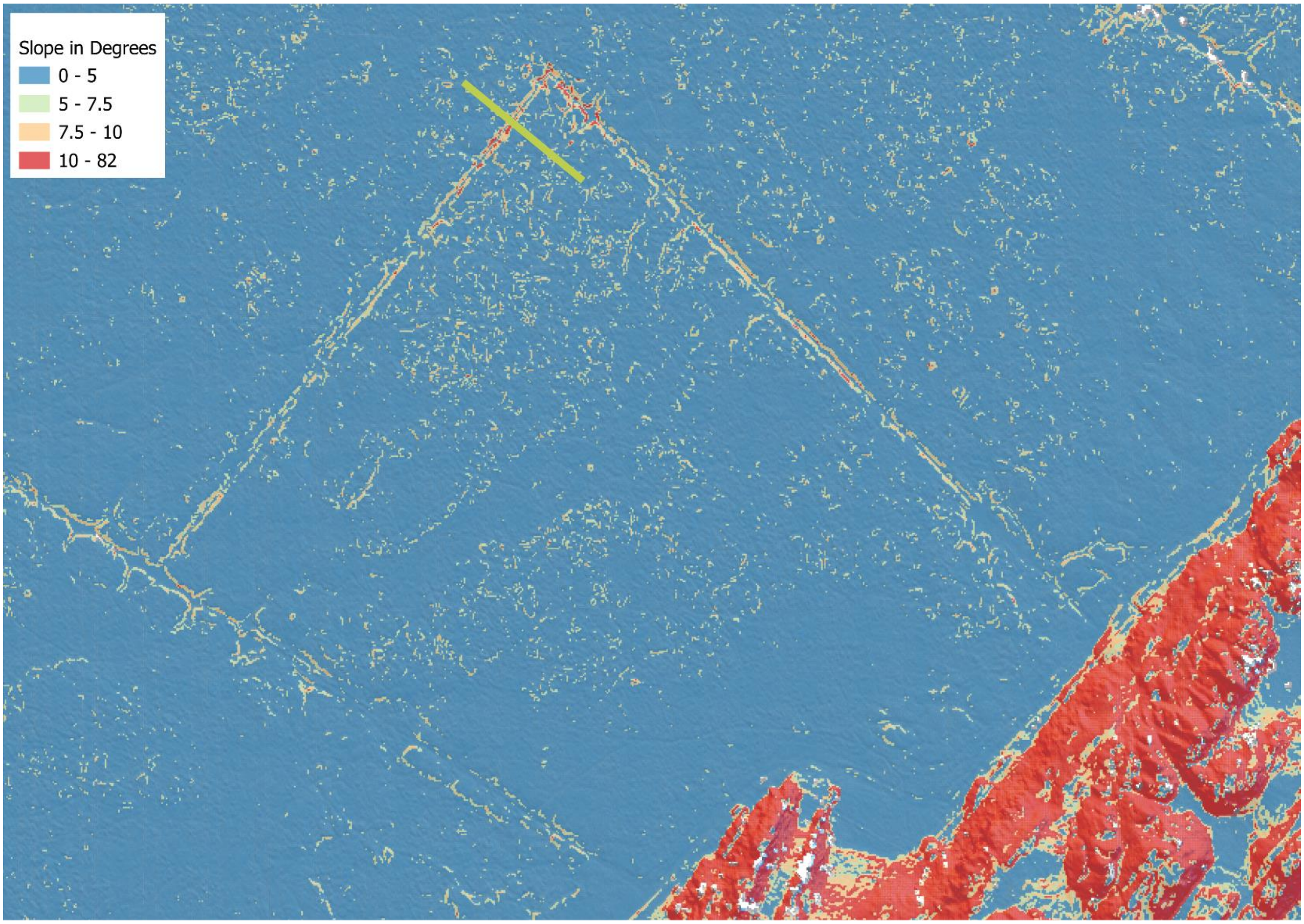
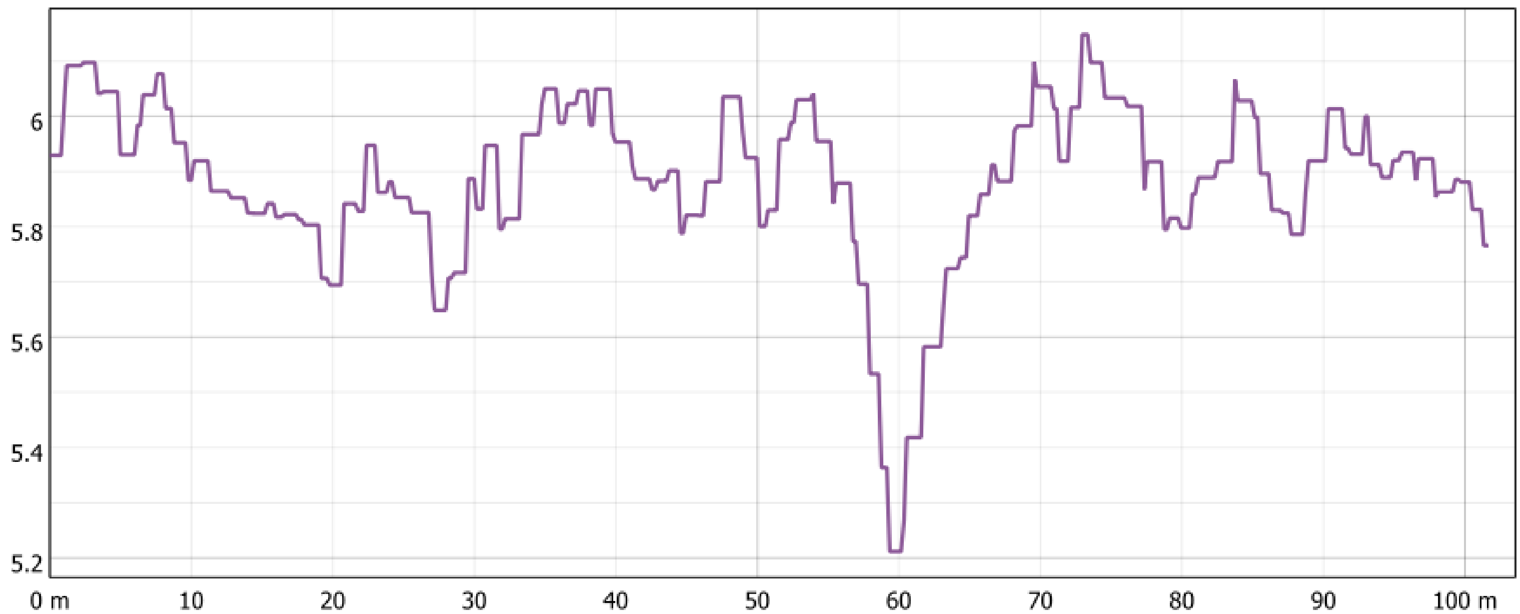


Figure 19. Slope in degrees and profile view section (green line)



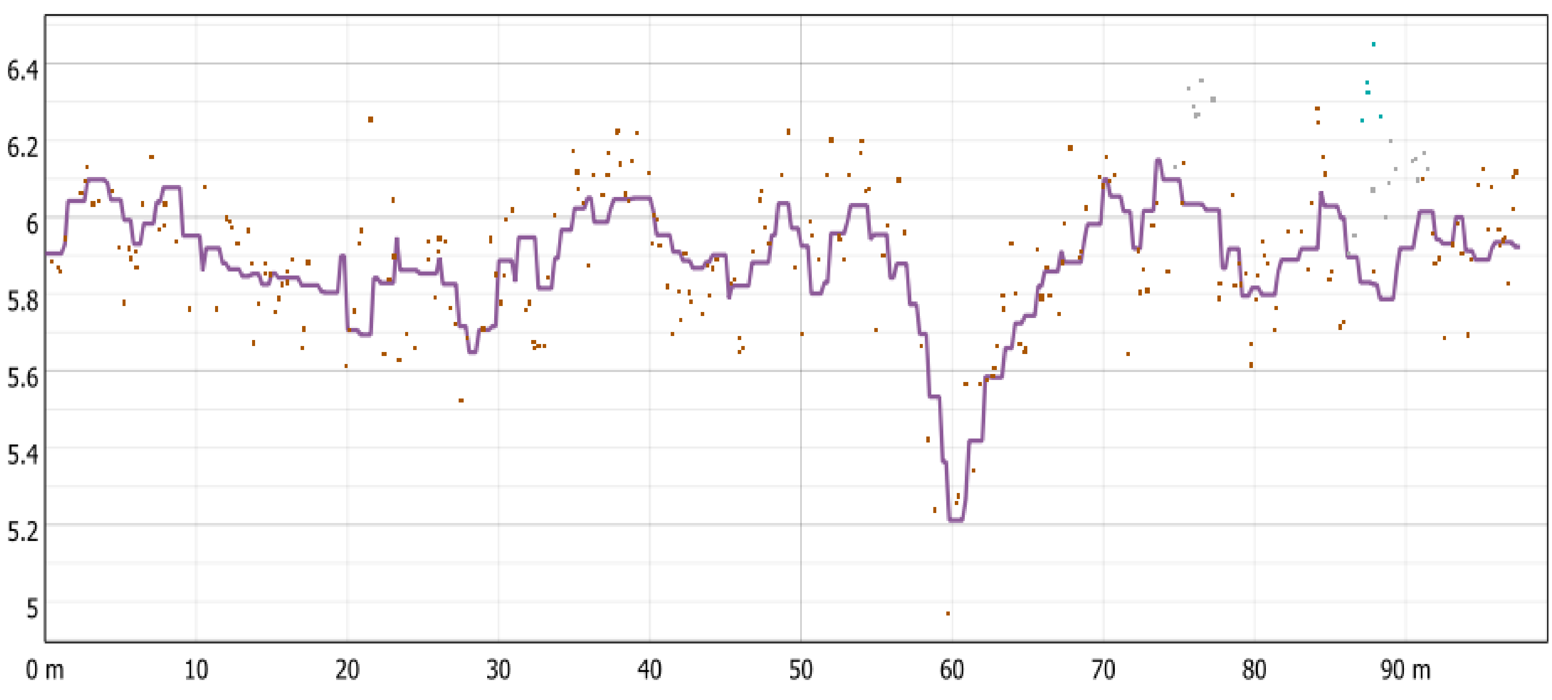


Figure 20. Profile view of the above section.

The next step included the comparison of the found drainage canals and ditches with other available drainage mapping datasets derived from satellite imagery (without LiDAR).

A dataset like that, specifically for peat habitats and conditions has been developed from The James Hutton Institute and it called the Scottish Peat Condition dataset. The dataset was compiled using several existing habitat datasets that include peat habitats and by filtering them and combining their information a model was created that show peat condition across Scotland and their drainage channels. In the following map a comparison of the previous area of the case study is presented where the Peat condition model has clearly missed some of the drainage canals which are clearly visible in the DTM and Hillshade model.

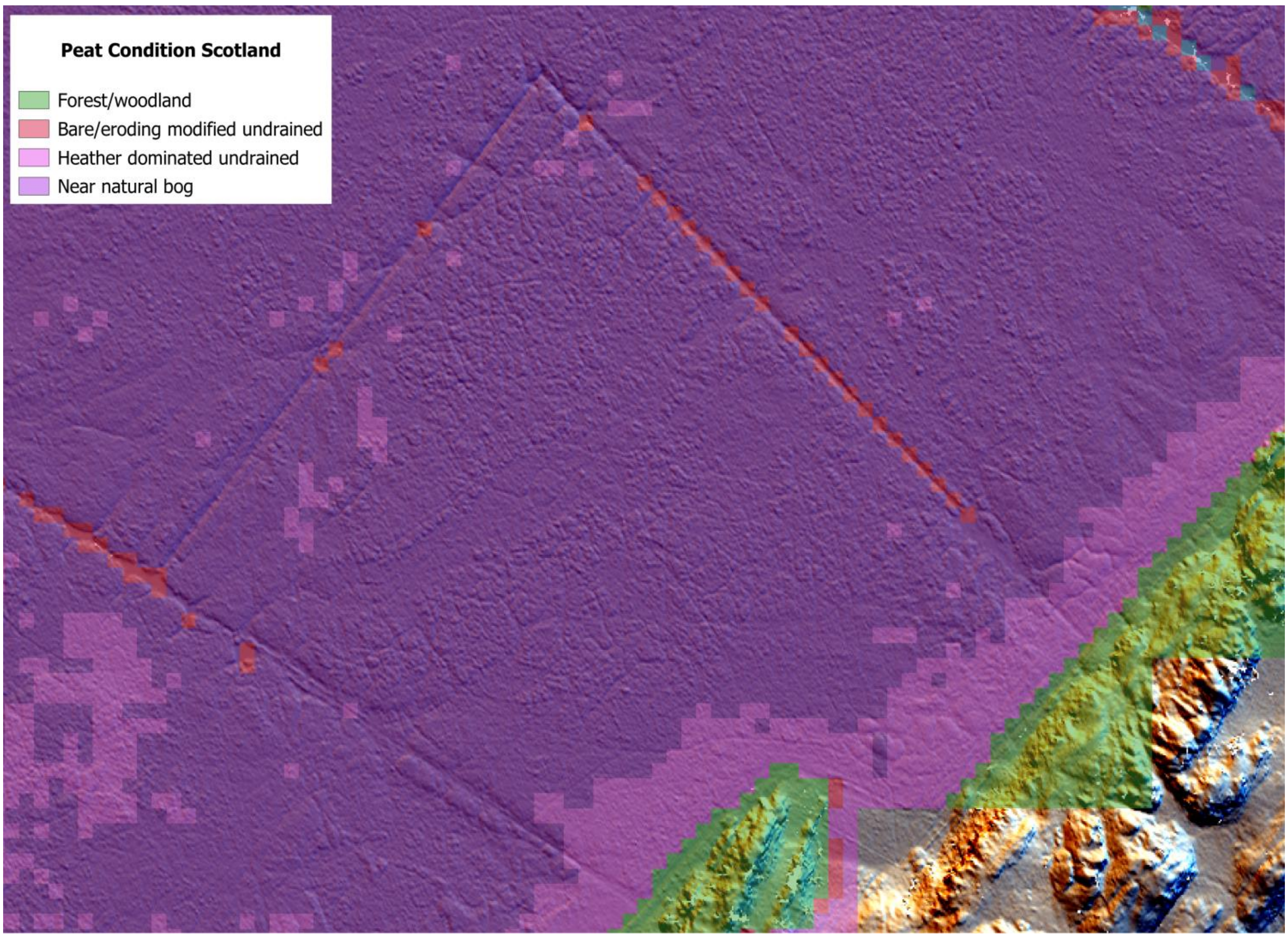


Figure 22. Comparison of Peat Condition Scotland and the Multidirectional hill shading.

As seen in the map, the Peat condition model only manages to identify as the drainages (marked in red pixels) as eroded/eroding only partially, missing most of the drain that runs North/Northeast direction.

This is an example of how accurate a LiDAR DTM can be and how it is possible to quickly identify eroding and drainage in peat habitats which an important feature in managing and restoring such habitats.

Another metric that can be derived quickly from the LiDAR DTM, is the calculation of Peat extraction from an area. The high detail of the DTM can produce a relatively accurate volume of the peat extracted from the area and it can be identified more easily compared with other methods. In the Moine Morr area there is a very notable area where Peat extraction for domestic use is quite noticeable. Below is the map of that area plus a 3D representation of it that shows the level of extraction.

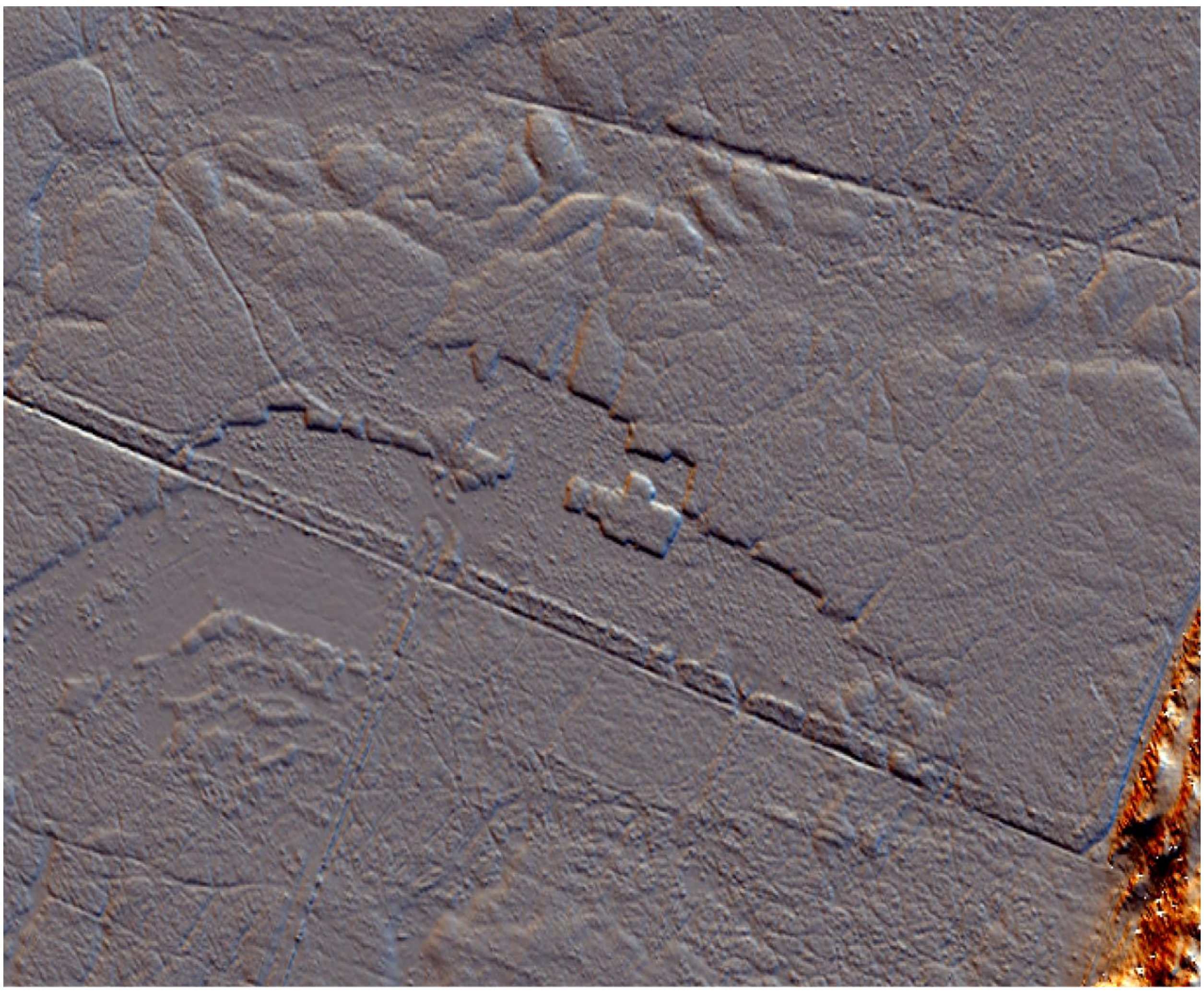


Figure 23. Area of domestic peat extraction.

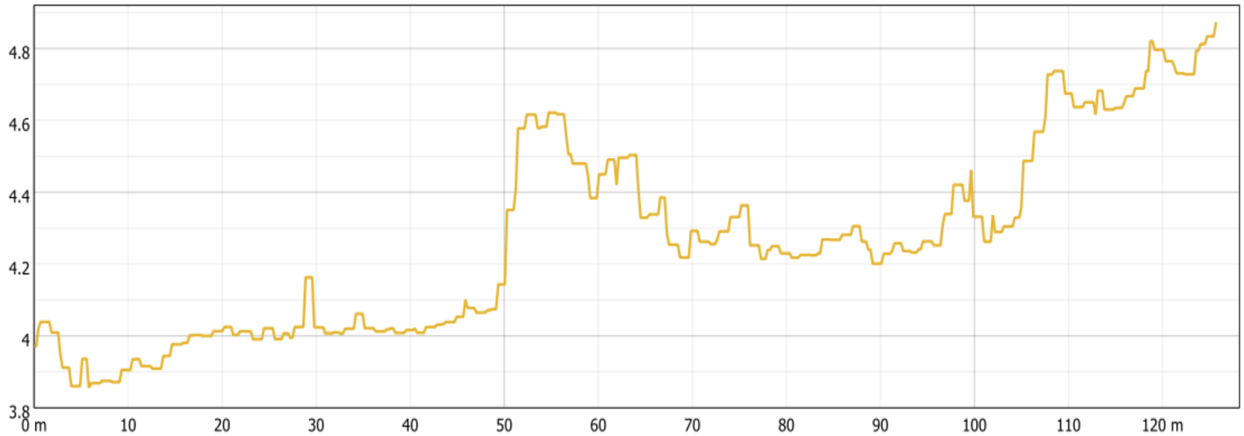


Figure 24. Profile view of the peat extraction

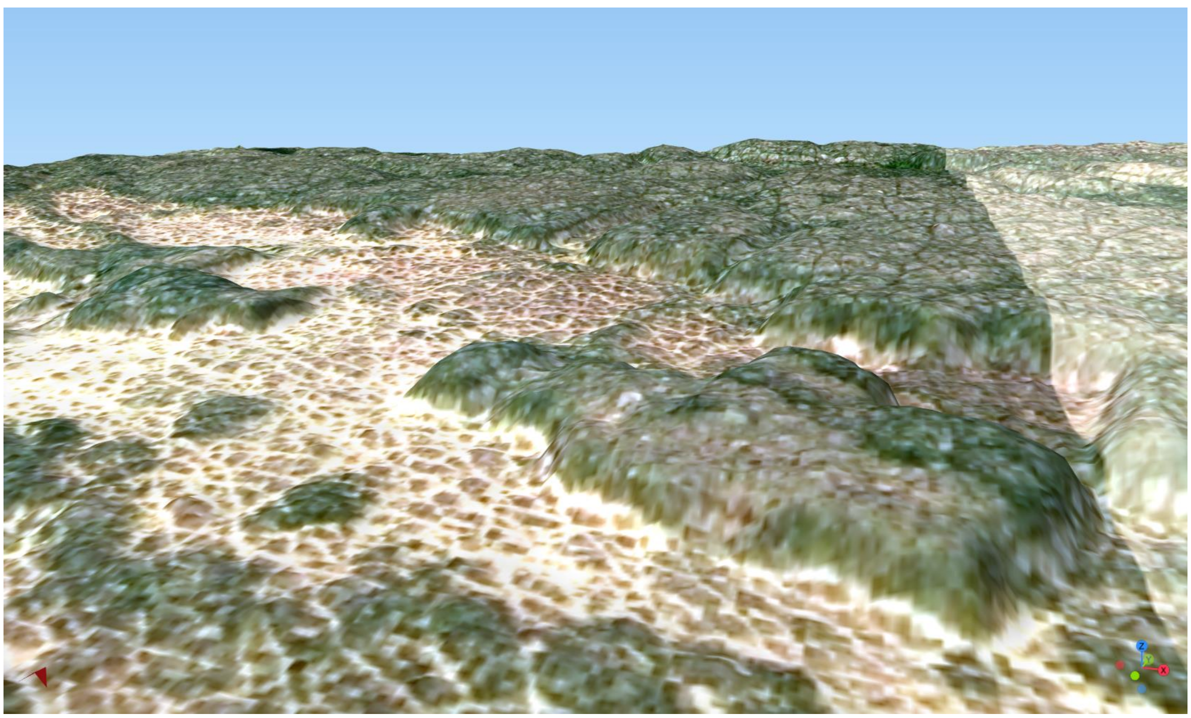


Figure 25. 3D visualisation of the extracted peat

A seen in the 3d map and in the elevation profile, there is significant difference in depth as the profile is viewed from south to North and the consistency in the same (rectangular) suggest that this area has seen domestic extraction of Peat. A useful metric for this would be to calculate the volume extracted, which can lead us to conclusions of the significance of Peat uses in the local area and how the volume of extraction can affect the Peat condition.

To calculate the volume of the peat extracted from this area, some steps were followed in QGIS3.

1. Digitize a polygon area around the Peat extraction.
2. Clip the DTM based on the digitised polygon.
3. Use the Raster Surface Volume algorithm in QGIS to calculate the extracted volume.

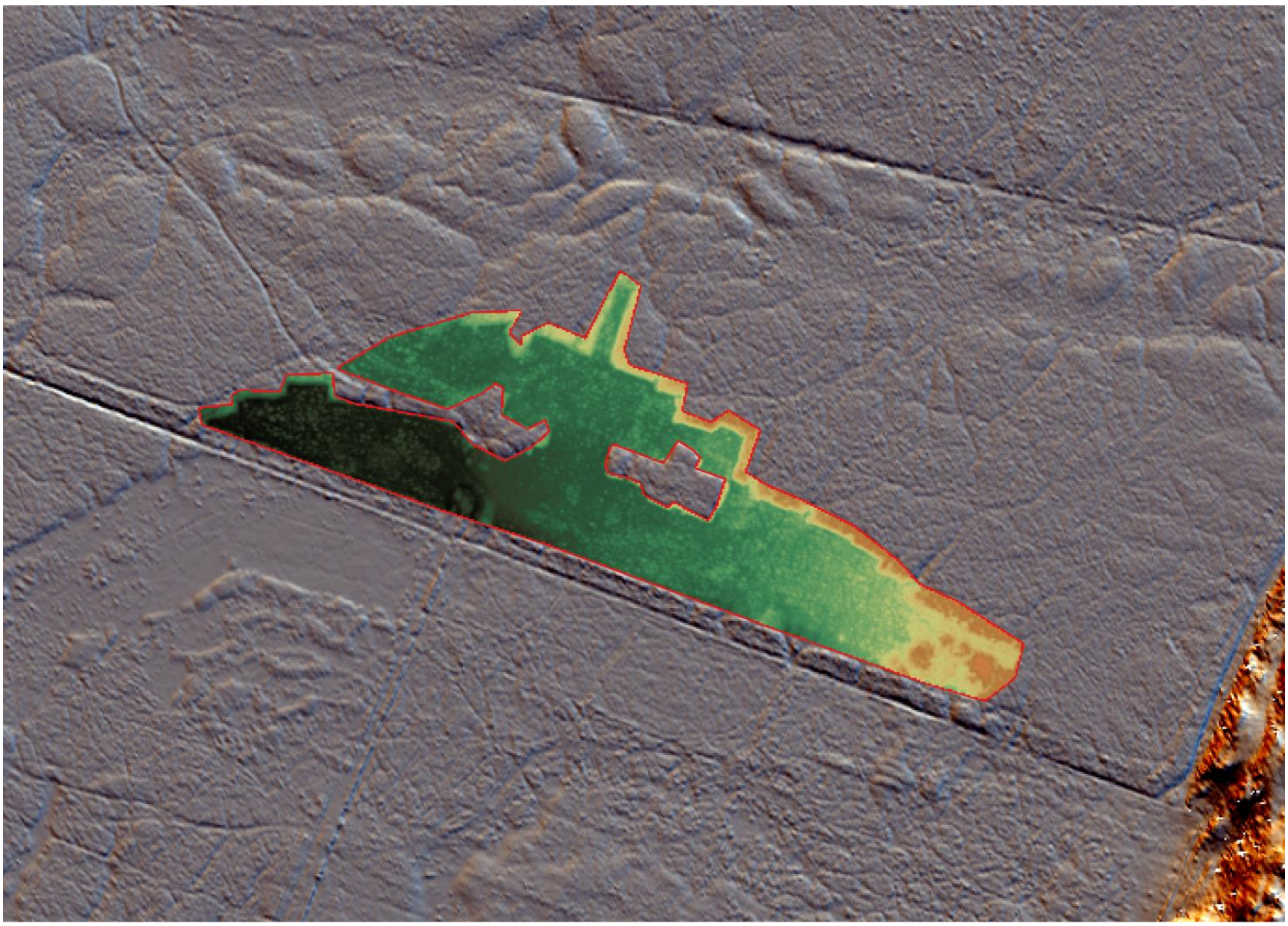


Figure 26. Calculate volume of extraction

The calculation of the extracted peat volume being calculated considering a max height of the extracted peat at 5m as shown in the previous graph.

The resulting algorithm produced the following result:

Volume in cubic meters	Area in square meters	Pixel count
20184.39	27537	27537

Table 2. Calculated peat volume

This calculation shows that across an area of 2.7537 hectares a total of 20184 cubic meters have been removed.

Using reverse calculation of the height of the missing peat and the actual size of each pixel we can also visualise the extracted peat.

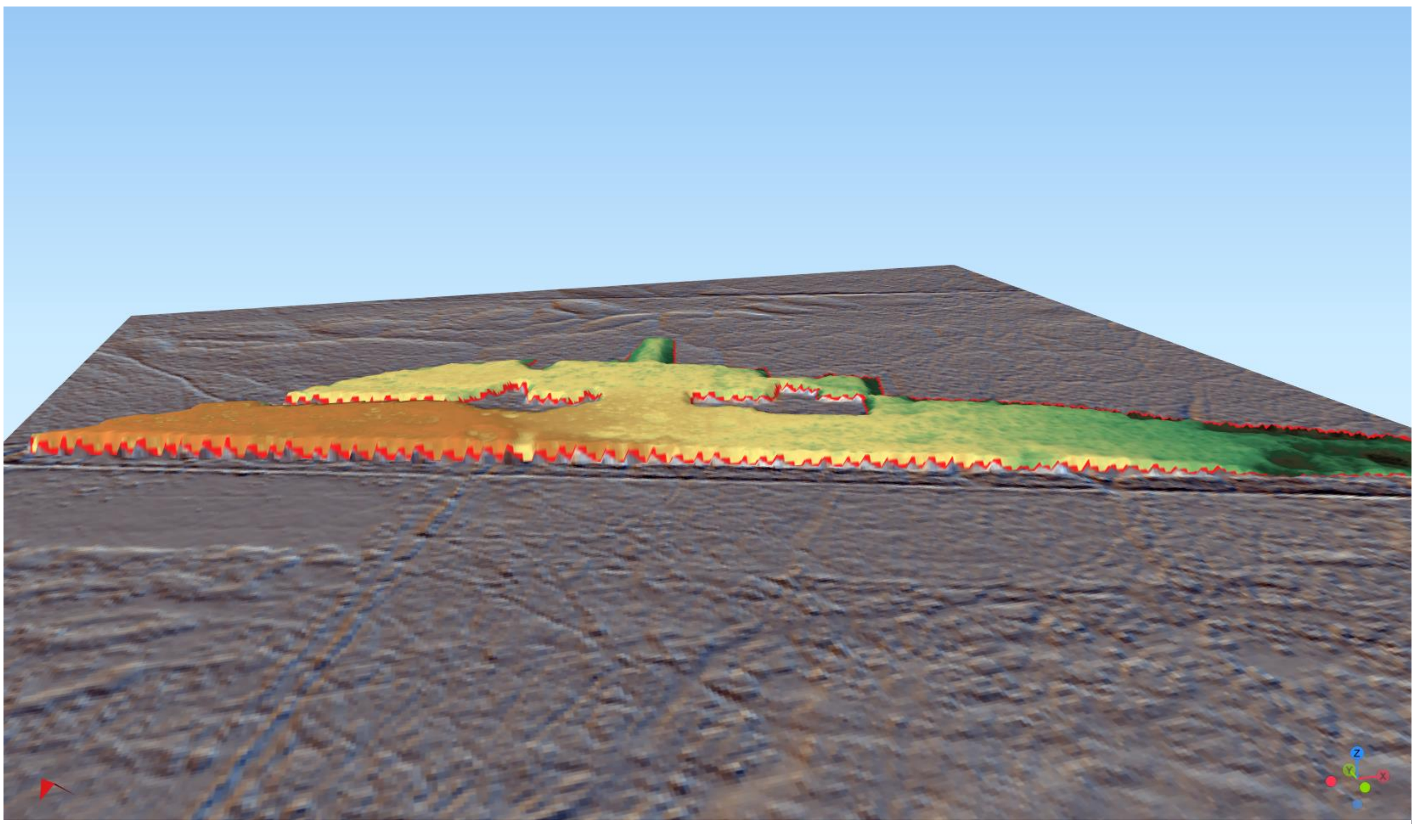


Figure 27. 3D Visualisation of the volume of extracted peat.

The visualization also enables us to see where most of the extraction has happened (orange area in the map) showing that most of the extraction has taken place in the eastern part of the site. This can help with identifying how severe the peat extraction was in the place where it most likely occurred.

At this point it was beneficial to calculate some other metrics to determine the general drainage characteristics of the site.

This was achieved using the drainage algorithms provide with SAGA GIS which is an accompanying GIS software that come with every QGIs installation.

One of these has been the calculation of the channel network over the reserve. This SAGA GIS algorithm takes as input the DTM and can produce a channel network based on gridded digital elevation data. The channel network can assist in detecting potential drainage sites and have targeted treatment to them.

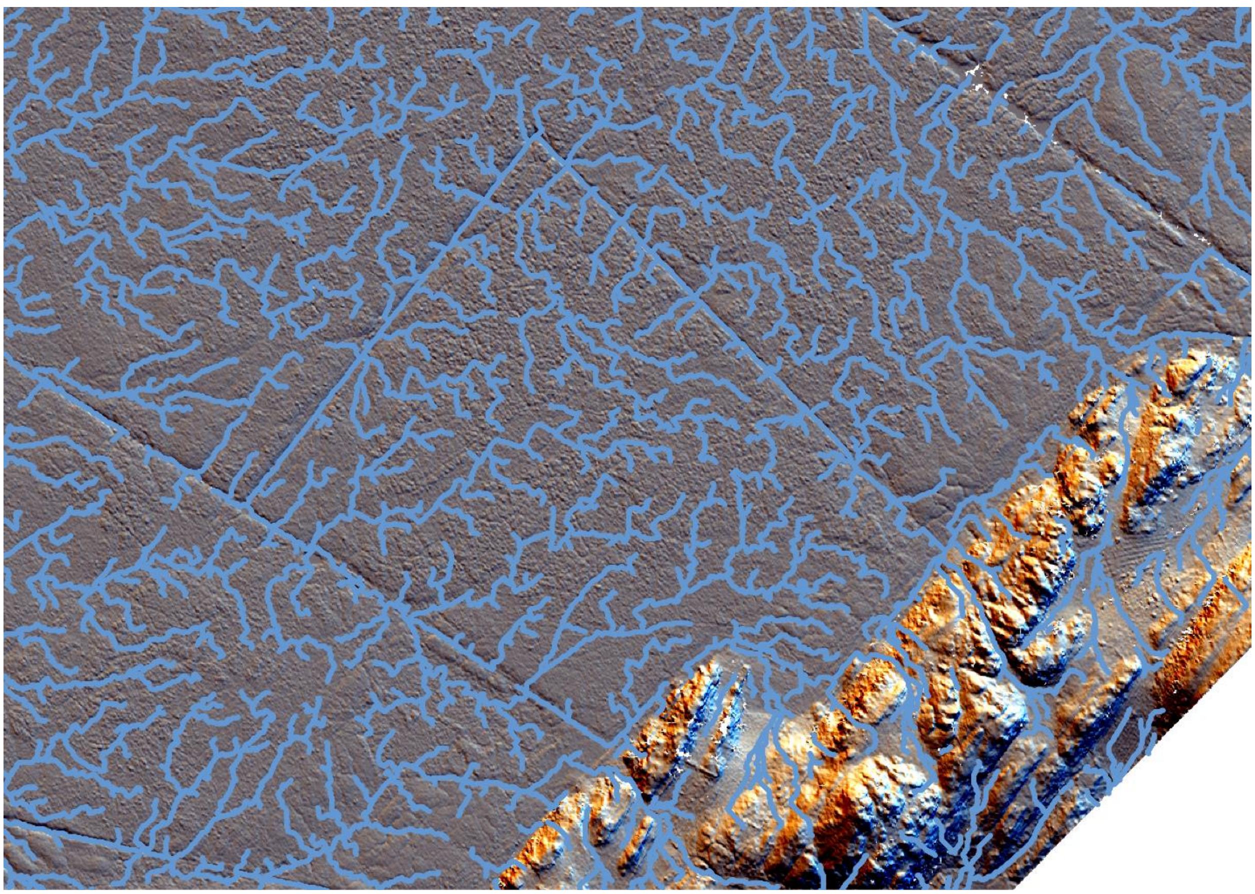


Figure 28. Channel Network.

The channel network produced by the SAGA algorithm has also calculated the order of the streams using the Strahler stream order, which defines order 1 streams as stream reaches that do not have any other reaches draining into them. When two stream reaches of different order join the order of the downstream reach is the order of the highest incoming reach. When two reaches of equal order join the downstream reach order is increased by 1. When more than two reaches join the downstream reach order is calculated as the maximum of the highest incoming reach order or the second highest incoming reach order + 1. This generalizes the common definition to cases where more than two flow paths reach join at a point. This- assists to estimate how flow oath is drained to other drainage canals and streams and help see which one contribute more to the drainage of the Peat.

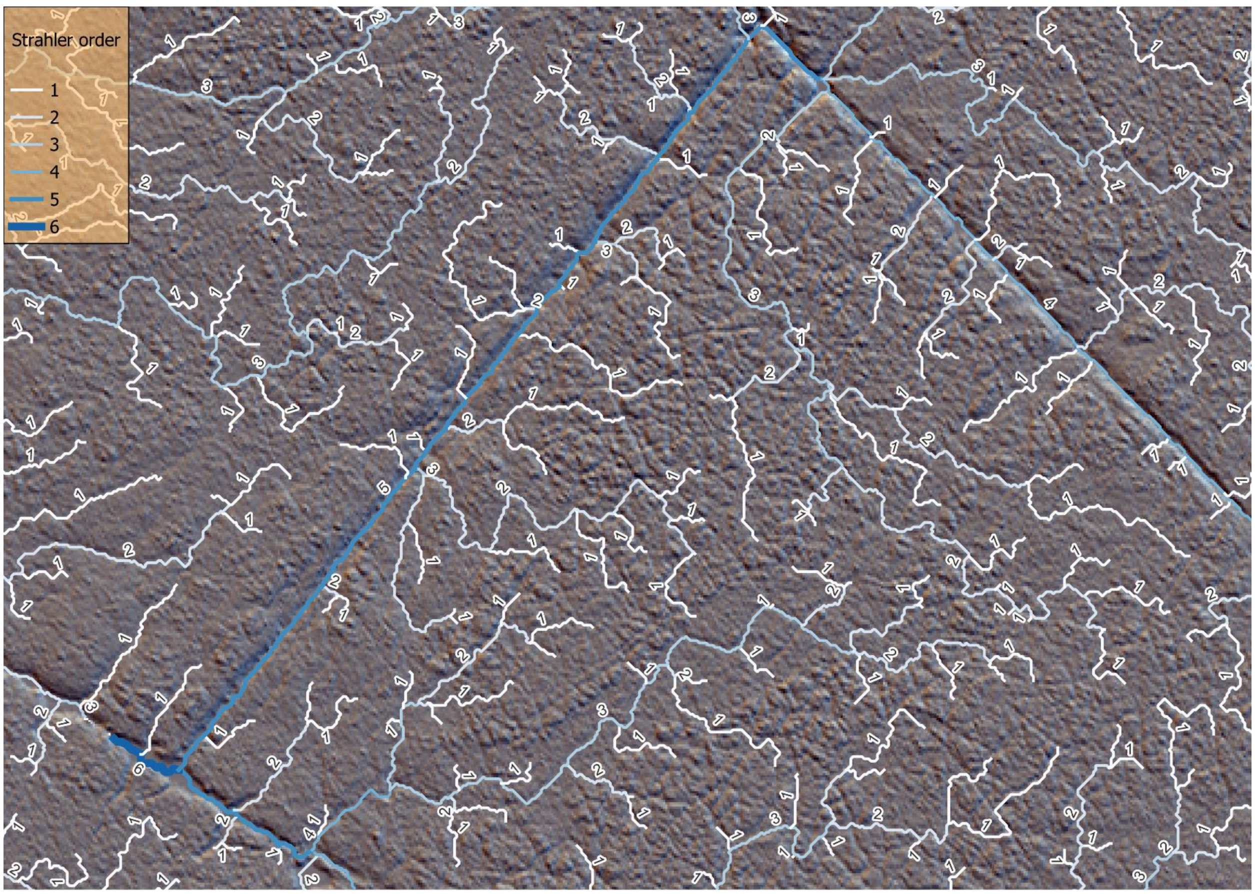


Figure 29. Channel Network with Strahler Order

Another calculation that was made was to calculate the Channel network elevation points. This was made by using SAGA GIS algorithm, Profile from lines. This will generate a layer of points which will extract the elevation along the streams. This will assist the elevation of the drainage canals and it also assists to realise how water will flow to lower heights. It also allows to estimate the depth of the drainage channels. Below is the statistics calculated for all the drainage channels in the reserve.

Analyzed field	LENGTH
Count	9881
Unique values	1540
NULL (missing) values	0
Minimum value	1
Maximum value	334.9898987
Range	333.9898987
Sum	320521.182
Mean value	32.43813197
Median value	23.97056275
Standard deviation	29.34380333
Coefficient of Variation	0.904608297
Minority (rarest occurring value)	11.41421356
Majority (most frequently occurring value)	2.414213562
First quartile	12.07106781
Third quartile	43.87005769
Interquartile Range (IQR)	31.79898987

Table 3. Channel network statistics.

To calculate the depth of the drainage channels was very tedious because of the varying altitude of the geological features across the reserve. However, as an example calculation was performed for a specific drainage canal to demonstrate how this would work and how that results can be further used. For the calculation, a buffer of 4 meters around the canal. For this the buffer algorithm of QGIs was used. Then the maximum value of DTM was calculated suing the Zonal statistics algorithm of QGIS3. This gave the average maximum value of the height on the area covered by the buffer. The final step was to subtract the values of the elevation that were extracted along the stream from the maximum values that were calculated from the zonal statistics. This was achieved by using the join by location algorithm that join attributes from the two layers mentioned above, and then by performing a subtraction of the value of elevation using the field calculator of QGIS.

The results were summarised below.

Analyzed field	Depth
Count	492
Unique values	267
NULL (missing) values	0
Minimum value	0.525
Maximum value	1.207
Range	0.682
Sum	506.306
Mean value	1.029077236
Median value	1.0435
Standard deviation	0.12780399
Coefficient of Variation	0.124192807
Minority (rarest occurring value)	0.525
Majority (most frequently occurring value)	1.096
First quartile	0.964
Third quartile	1.1255
Interquartile Range (IQR)	0.1615

Table 4. Depth of canal statistics.

From this we can notice that the mean depth of the canal is 1.02 meters, with the maximum depth being 1.2 meters and the minimum depth being 0.5 meters.

Below is a map of the canal and the calculated depth along its length.

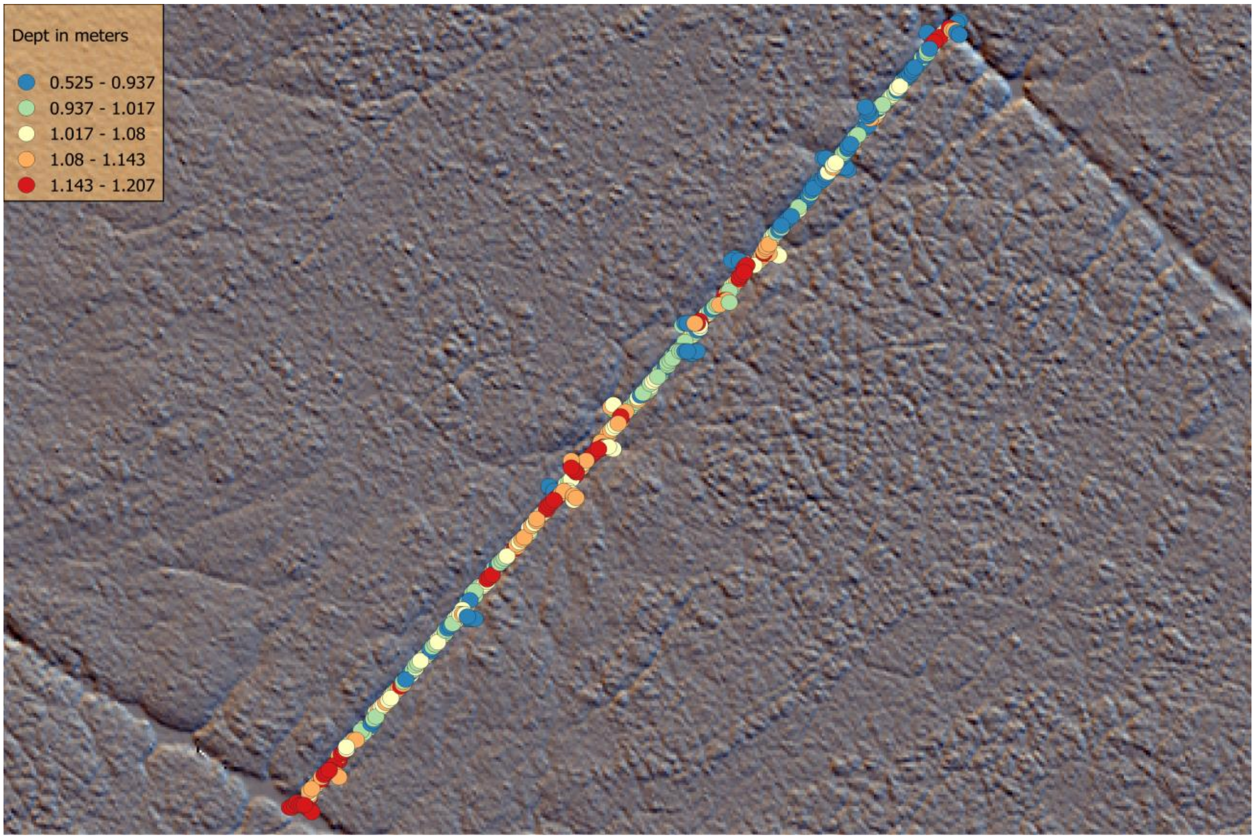


Figure 30. Calculate depth point of drainage canal.

Conclusions

In this document, the basic principles of working with LiDAR data with Opensource software was analysed.

Firstly, some simple steps to loading and generating data and maps from LiDAR raw data as las/laz files was demonstrated to familiarise users with limited or nonexistence experience in this kind of data. The main point of the document is to note that in general the most basic data transformations and generation from LiDAR data is not complicated and can be done easily.

In the second part a more detailed approach was conducted to highlight the importance of LiDAR data in specific sectors with conservation management such as Peat restoration and monitoring, and how useful LiDAR data can be in this case.

It is worth mentioning that the applications of LiDAR data do not stop here and the complexity and analysis that can be done with these is especially important and numerus.