

Portfolio: Applied GIS and Remote Sensing

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1. Component 1: Digitisation and Visualisation

1.1. Overview

Traditionally to map and visualise different habitats on a site, a phase 1 habitat survey would be conducted. This typically involves using an ordinance survey map and noting the vegetation species and extent from the ground (JNCC, 2016). This was a slow process with the first nationwide survey in Wales beginning in 1979 and only being fully complete in 1997 (Blackstock, 2010). In the following years satellite data was used to update the phase 1 habitat survey making Wales the first European country to produce a nationwide habitat map using satellites (Lucas et al., 2011). This process was considerably faster than the physical on the ground survey and shows how powerful satellite imagery can be for habitat mapping.

In order to effectively utilise GIS to create maps, real world data must first be digitised. This is the process of taking geographic data and converting it into a digital format that can be utilised within the GIS software. This can be done in a number of ways such as remote sensing from satellites to automatically capture geographic data such as elevation data (Lillesand, Kiefer and Chipman, 2015), or physically going to the site to collect data. This real-world data can then be visualised on a map to better represent this data.

This section of the portfolio will utilise this process by creating a map of a local site by digitising real world data. This data was collected through both methods listed above and will be represented in an appropriate format relevant to the data type. The formats include vectors such as map points, lines and polygons as well as the use of rasters.

The chosen software used to digitise the spatial data is QGIS. This is an open-source software designed to allow for viewing, editing, printing and analysis of geospatial data. This allows for a much more accessible and customisable option compared to other software such as ArcGIS.

1.2. Site Description

The site that was selected for this project was a local park known as Llwydcoed Park (Figure 1). It is located just outside of the town of Aberdare and is a small site which according to the terrestrial phase 1 habitat survey, is mostly assigned the code of J.1.2 which designates it as amenity grassland (NRW, 2023). The site does contain a range of trees, a small playground and a wooded embankment known locally as the Planto. While it is a relatively small site consisting of about 3 acres, it does have a range of features, plant species and elevations that can be represented digitally by GIS.



Figure 1 ESRI Satellite image of Llwydcoed Park created by Author in QGIS

1.3. Vectors

As stated previously, this project will utilise vectors to represent data. Vectors indicate the exact position of points using coordinates (Demers, 2009). An advantage of vectors is that the points are incredibly precise and are relatively low storage compared to alternate methods such as raster files (Clarke, 2024). However, unless the exact coordinates of each point are known, it can be hard to accurately map them based on satellite imagery. This can be exacerbated by features such as tree cover and clouds which can block the view of the ground partly or entirely (Mesev and Walrath, 2007). This is why it is important to incorporate either remote sensing techniques or on the ground data collection to improve the accuracy of any visualisation and analysis projects.

1.3.1. Points

On this map (Figure 3), points were mapped out to represent where trees were located on the amenity grassland. The tree positions were located through satellite imagery and so may not be exactly accurate due to issues such as the canopy obscuring the view. In order to get more accurate location data as well as other data not discernible from satellite imagery, an on the ground survey can be conducted. Other data such as tree species and height can also be captured and stored alongside the location data in an attribute table. An attribute table allows the user to create additional fields in which additional data can be added. For this attribute table, the species, tree height and any additional comments were included (Figure 2). All attributes in this project were estimations as there is no accurate way of collecting this data through just satellite imagery. There are methods of calculating tree heights using remote sensing such as canopy height models (CHM) which is derived from subtracting a digital terrain model (DTM) from a digital surface model (DSM) (Williams, 2024).

	id	Species	Height	Comment
1	1	Oak	2.4	Young Tree Planted in the last few years
2	2	Oak	2.6	Young Tree Planted in the last few years
3	3	Oak	2.3	Young Tree Planted in the last few years
4	4	Oak	2.7	Young Tree Planted in the last few years
5	5	Oak	3.0	Young Tree Planted in the last few years
6	6	Beech	13.0	Recently copiced by the council
7	7	Beech	15.0	NULL
8	8	Beech	15.0	NULL
9	9	Alder	16.0	NULL
10	9	Alder	12.0	NULL
11	10	Alder	14.0	NULL
12	11	Alder	10.0	NULL
13	12	Poplars	15.0	NULL
14	13	Beech	16.0	NULL
15	14	Beech	15.0	NULL
16	15	Beech	18.0	NULL
17	16	Oak	15.0	NULL

Figure 2 Attribute table for potential deciduous trees in figure 3



Figure 3 Map showing the location and estimated height of trees on the amenity grassland in Llwydcoed Park created by author in QGIS

Estimations for tree types were made based on existing knowledge of the site to demonstrate the different symbology that can be used. As previously stated in order to get accurate data on the tree types an on the ground survey should be conducted. In order to differentiate the tree species on the map, a different style and colour was designated to each species. This allows for quick and easy recognition when paired with the legend. The example tree heights are also displayed alongside the points to represent this data in an easily understandable way.

1.3.2. Lines

Lines are created by joining together a set of points. In this map (Figure 5), lines are representative of different footpaths that are located around the park. An attribute table is used to distinguish between different path types (Figure 4).

id		Material
1	1	Concrete
2	2	Concrete
3	3	Dirt
4	4	Dirt
5	5	Concrete
6	6	Concrete
7	7	Concrete
8	8	Concrete

Figure 4 An example attribute table for figure 5



Figure 5 Map of footpaths and their materials in Llwedcoed park created by author in QGIS

The footpath types are again examples and an on the ground survey would need to be done to confirm this. One of the concrete paths in the map above (Figure 5) create a closed loop. In order to ensure that there are no gaps and the loop is completely closed the snapping tool can be used (Figure 6) This ensures that all points are correctly joined together and prevents future issues such as incorrect calculations or broken line networks (Anderson, 2025).

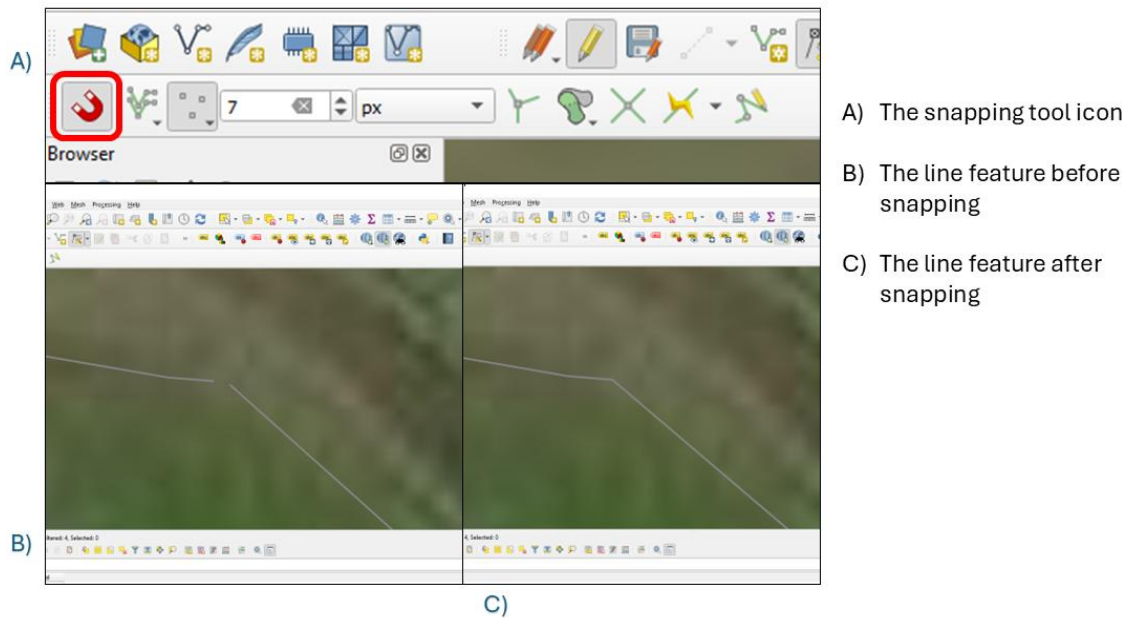


Figure 6 Demonstration on how the snapping tool works in QGIS

1.3.3. Polygons

Polygons are a closed loop shape that are used to visualise areas rather than points or lines. Polygons are often used to represent features that cover wide areas and have a well-defined boundary such as fields, building and lakes (Heywood, Cornelius and Carver, 2011) . In this project polygons are used to represent land cover of Llwydcoed Park.



Figure 7 Map showing the different areas of Llwydcoed Park and their area in m² created by author in QGIS

Showing the area of polygons on the map can help with visualising the size of the features. In order to calculate the area of each polygon the field calculator can be used (Figure 8).

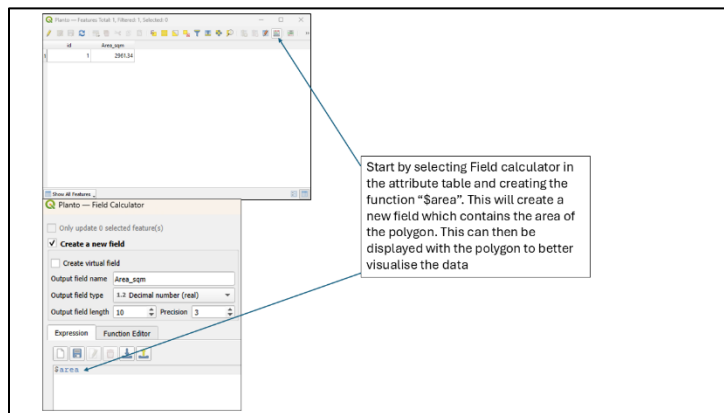


Figure 8 Demonstration on how to add polygon area size

1.4. Rasters

One of the drawbacks of vectors is that it is limited when representing complex and continuous data that may cover a surface e.g. Elevation data (Clarke, 2024). Every area of land will have a specific height value so instead of plotting each point to a specific coordinate, a grid of pixels can be used represent the values. This makes continuous and varying data easier to visualise and perform calculations (Mesev, 2007).

Using publicly available elevation data from the Welsh Government, (Welsh Government, 2024) the following map was created to demonstrate elevation differences on the site starting at the lowest elevation on the site (Figure 9).

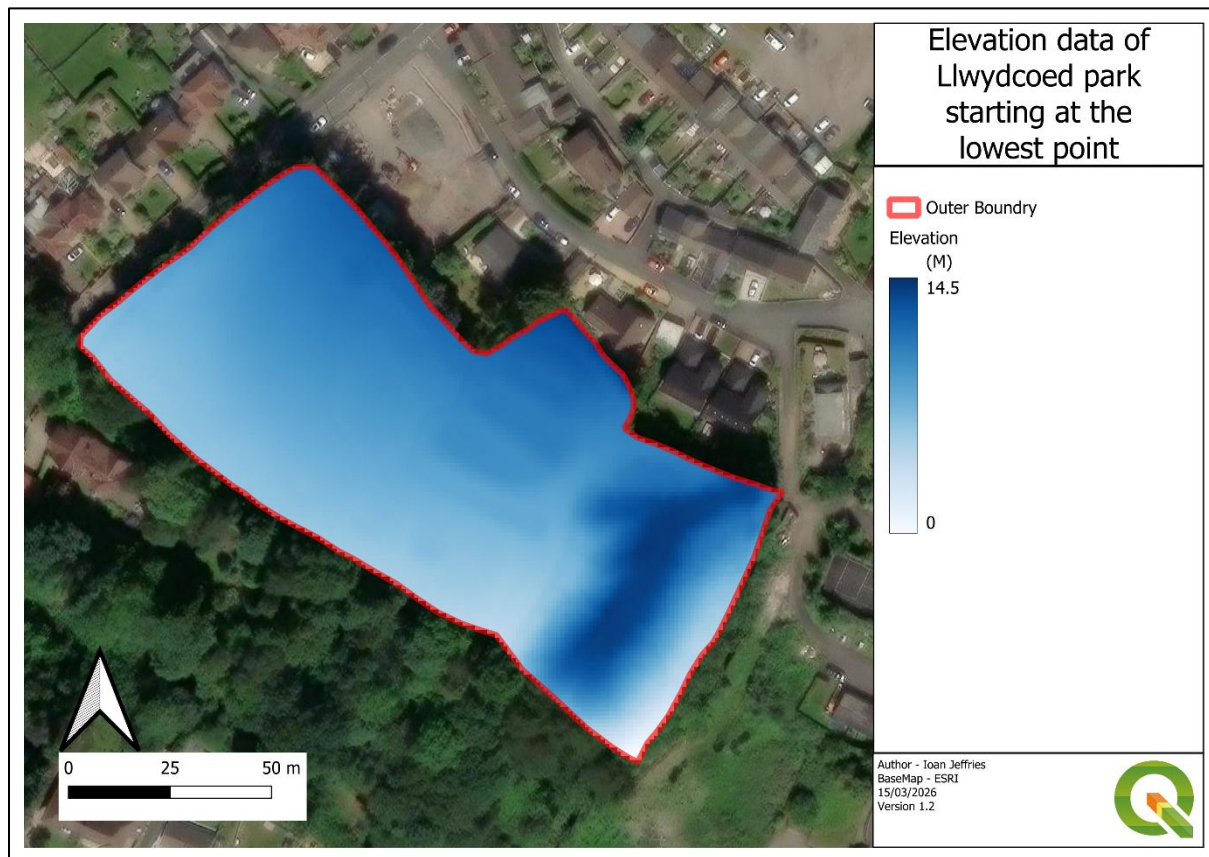


Figure 9 Elevation of Llwydcoed Park with 0 representing the lowest area of the site. Elevation Data from the Welsh Government (Welsh Government, 2024). Map created by author in QGIS.

Each pixel represents a different value and so can be visualised through differing colours depending on the height.

2. Component 2: Spectral analysis

2.1. Overview

Visual observations are incredibly useful and can provide lots of information about changes of a site, especially where conditions have shifted in a very noticeable way. For example looking at areas that have been effected by flooding such as the Velencia flash floods in 2024 (Figure 10). While these events are very easily visualised through visible light sensors, there are other landscape changes that are not as noticeable in the visible light wavelength and can be better visualised through other means.

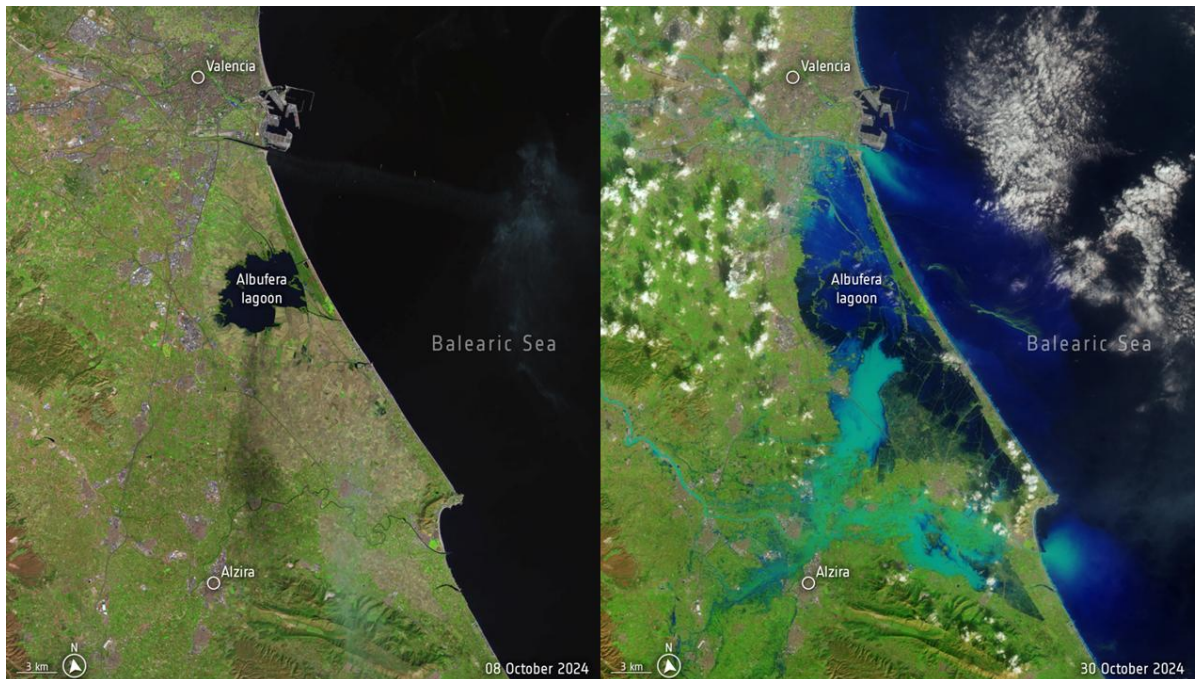


Figure 10 Landsat-8 imagery depicting the before and after of the Velencia flash floods in 2024 processed by the European Space Agency (ESA, 2024)

This section will look at how different wavelengths can be utilised by remote sensors to detect and better visualise these changes and how this can be applied to different maps to better understand what is going on in a landscape beyond the visual changes. This will be demonstrated through 2 practical examples. The first being the use of a spectrometer to look as how different surfaces are effected by different spectral aspects. With the second being a real world example of how spectral analysis can be used to monitor plant health and foliage cover.

2.2. Spectrometer

Remote sensors rely on electromagnetic (EM) energy readings to produce data. Whether the energy source is created by the sensor itself (active) or relies on energy produced by the sun (passive). It relies on this energy interacting with an object and reading the reflected energy hitting the sensor.

When electromagnetic energy interacts with any surface there are 3 potential outcomes which can occur (Gibson and Power, 2013);

- Reflection
- Absorption
- Transmission

Different materials will naturally absorb and reflect different levels EM energy from a specific bandwidth than others. For example, deciduous trees such as maple will typically reflect more near-infrared than coniferous trees such as pine meaning that sensors will pick up a higher reading of near-infrared over deciduous forests than coniferous (Figure 11).

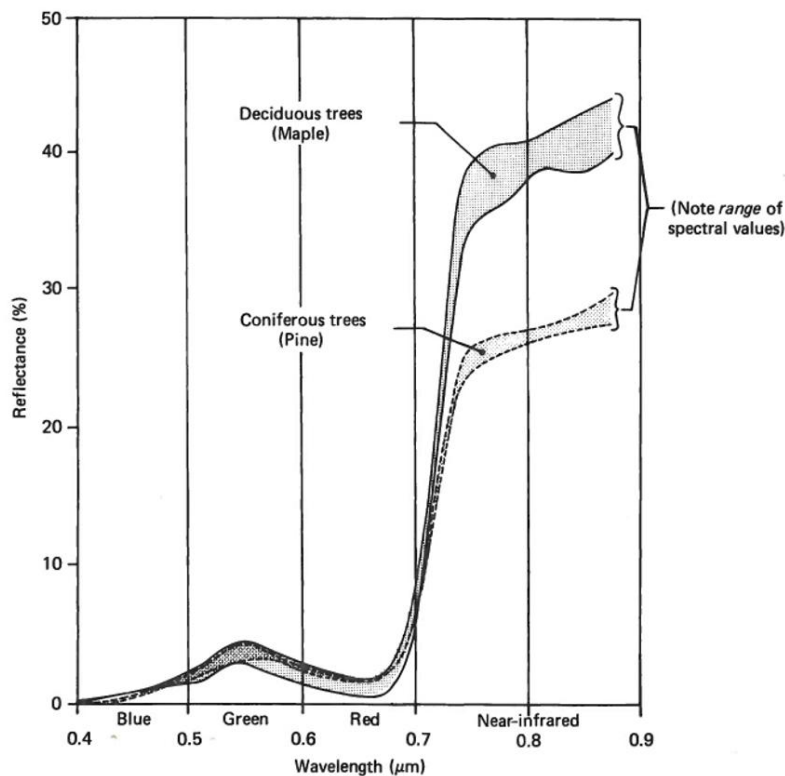


Figure 11 Spectral reflectance graph containing the range of reflectance from deciduous and coniferous trees (Kalensky and Wilson, 1975; Lillesand, Kiefer and Chipman, 2015)

In order to demonstrate this and how it can be utilised, readings were taken by a spectrometer from a number of different objects to demonstrate the different EM frequencies reflected ranging from the visible colours to near infrared. 4 different objects were measured by the spectrometer which are as follows;

- Green healthy leaf
- Red stressed leaf
- Daffodil Petal
- Driftwood

During measurements of the objects there was an error recorded which has been labelled as “Anomaly” so that result should be disregarded.

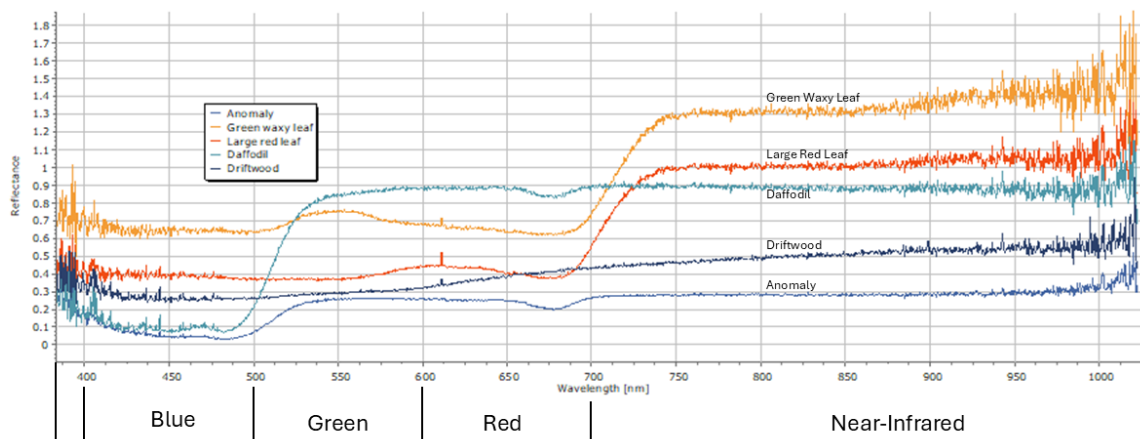


Figure 12 Spectral reflectance graph showing the results from the 4 objects as well as an anomaly that should be disregarded

The results from the spectrometer show the key differences between the healthy and stressed leaves and the differences in reflectance. Healthy vegetation typically has a higher reflection of near-infrared than stressed vegetation (Gibson and Power, 2013) (Figure 13). However, stressed vegetation typically has a higher reflectance rate of the green and red bands due to decaying chlorophyll which leads to a reduced absorption rate which is not seen in this graph (Roman and Ursu, 2016). This could be due to a number of reasons such as a sensor calibration error or a sample error. Dead material such as bare soil or drift wood follow a fairly linear trend which can be seen in the graph (Figure 12).

Comparing these results with an example graph (Figure 13) show a fairly similar result with the linear progression of the dead material and the reduced near-infrared reflectance of the stressed plant compared with the healthy green leaf. The only area the 2 diagrams appear to diverge is the reflectance levels of the green and red bands.

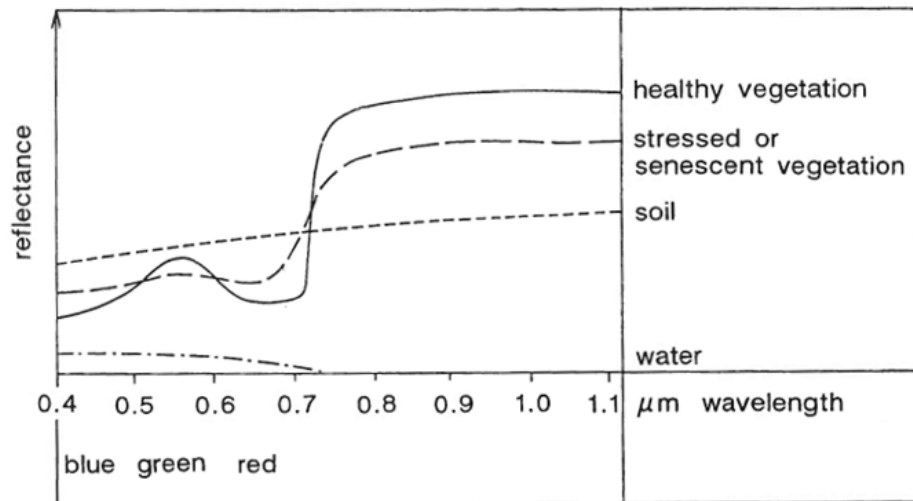


Figure 13 Example diagram of the reflectance of healthy and stressed vegetation, as well as soil and water (Gibson and Power, 2013).

As can be seen in the diagram, the reflectance level seems to dip for red reflectance before raising again for the near-infrared. This is often known as the red edge and can be a great indicator for the presence of healthy vegetation (Prost, 2014).

2.3. Spectral Index

The idea that healthy plants reflect high levels of near-infrared light while absorbing more visible light means that it is possible to assess plant health and cover based on the wavelengths that are reflected into the atmosphere. In order to identify areas of healthy vegetation, a spectral index can be used to quantify and highlight areas of high infrared reflection. The normalised difference vegetation index (NDVI) is a metric designed to quantify the health and density of vegetation using remote sensing methods (Rouse et al., 1974). This index utilises the fact that green vegetation will naturally reflect more near-infrared radiation while less green and sparse vegetation will reflect less. By comparing these values, NDVI creates a useful ratio to determine levels of photosynthetic activity (Purkis and V Klemas, 2011). NDVI can be expressed as follows:

$$NDVI = \frac{NIR - R}{NIR + R}$$

NIR = Near-Infrared

R = Red

Figure 14 NDVI formula (Kalensky and Wilson, 1975)

In order to measure the NDVI of real world sites, publicly available remote sensing data can be utilised such as data sourced from the sentinel-2 satellites. Sentinel-2 consists of 2 satellites in sun synchronous orbit which are both equipped with a multi spectral instrument (MSI) (CDSE, 2023). The MSI consists of 13 spectral bands which are able to monitor visible, near-infrared and shortwave infrared at a spatial resolution between 60m and 10m (EO Portal, 2025). This data is freely available to both organisations and the general public through the Copernicus browser (CDSE, 2026).

2.4. Christmas Island

In order to demonstrate the potential uses for these monitoring methods, Christmas Island will be used as an example. This is an island in the Indian ocean about 870 miles northwest of Australia. Most of the island is covered in tropical rainforest and so is almost completely covered in dense green foliage (Britannica, 2018).

Spectral data was downloaded from the Copernicus browser for 2 separate dates as a comparison;

- 24/04/2021
- 30/11/2023

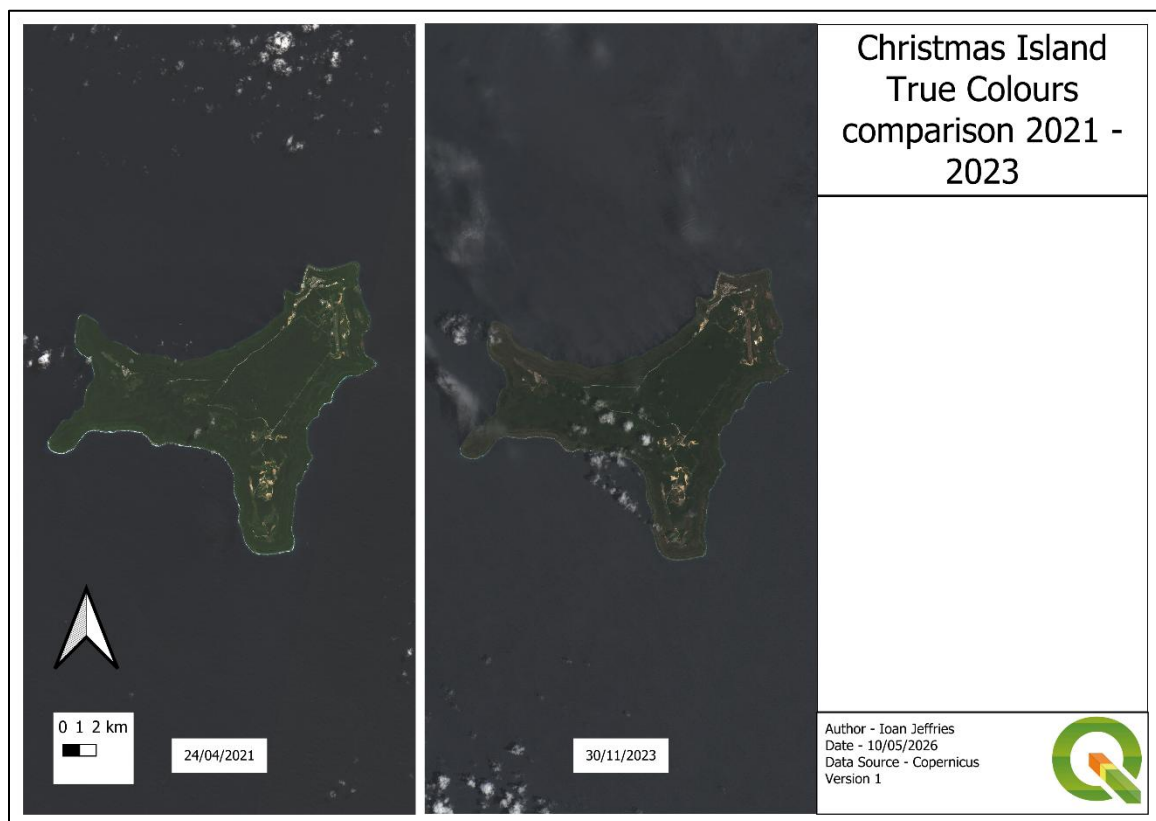
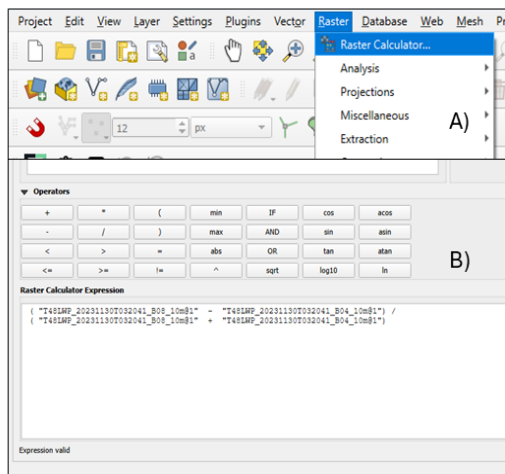


Figure 15 True colour maps of Christmas island during 2021 and 2023

In order to perform a fair comparison of foliage cover, results should be taken within the same season to account for seasonal variation. Christmas Island exists within a tropical region and so only has 2 seasons, the dry season and the wet season (WorldData, 2026). The dates selected were both within the wet season. These dates were also selected as there was minimal cloud coverage which won't effect the capabilities of the near-infrared sensors but can limit the visibility of the visible light wavelengths (NASA, 1999).

Performing the NDVI calculation within QGIS using the raster calculator function allows for a visualisation of the scores (Figure 16).



A) Selecting the raster calculator tool

B) The NDVI formula being inputted with the 2023 Sentinal-2 data

Figure 16 Process of performing the NDVI calculation in QGIS

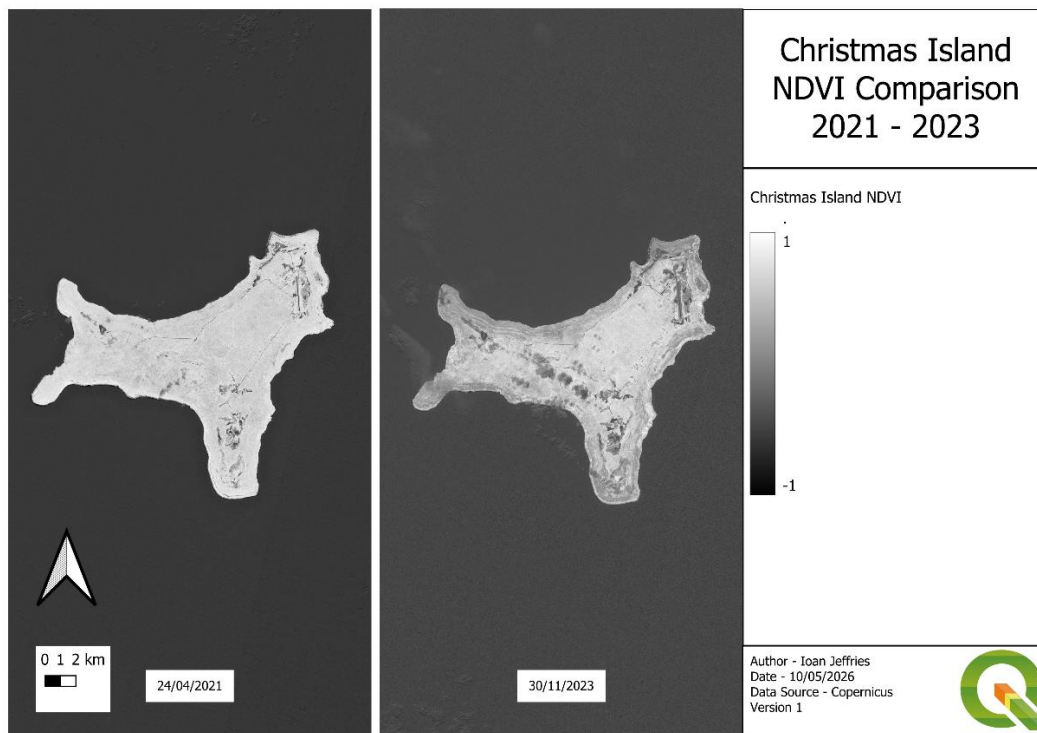


Figure 17 Christmas Island NDVI Comparison

Having both maps side by side helps to illustrate the variation in foliage coverage. Something worth noting is that on the map for 30/11/2023 (Figure 15), there is slightly more cloud coverage which can cause invalid results. These maps can also be subtracted from one another to better illustrate areas of improving/regressing vegetation (Figure 18).

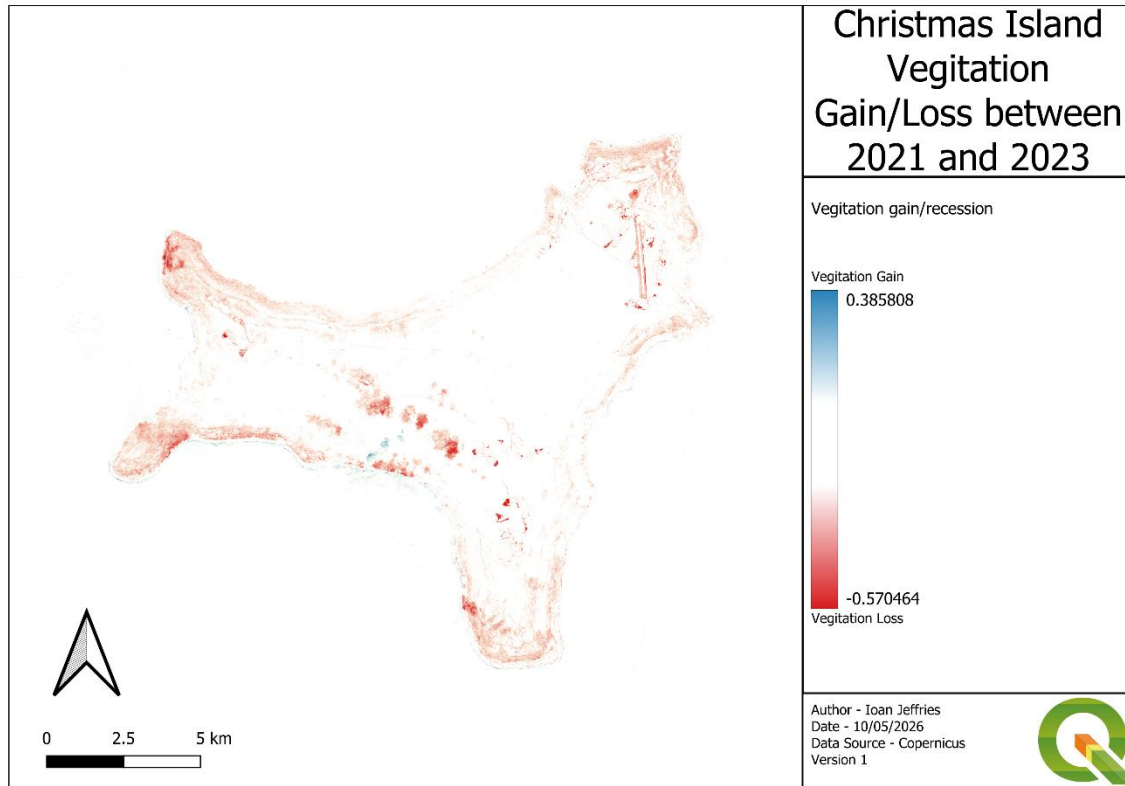


Figure 18 Map showing areas of vegetation gain/loss on Christmas Island

Comparing this map to the true colour map (Figure 15), it can be noted that 2023 had more cloud coverage. This has led to a number of false results showing vegetation loss where cloud coverage exists. This is an example of one of the limitations of remote sensing as cloud coverage can skew results. A possible solution to this issue would be to exclude pixels containing cloud cover to avoid bias and misleading results (Hameed, 2020).

3. GIS Field Data Collection

3.1. Overview

As discussed in component 1, there is only so much data that can be collected from satellite imagery and remote sensing. On the ground surveys are necessary in certain studies and can provide a lot more accurate data than remote sensing in certain instances (Yan et al., 2015). When conducting an on the ground survey, it is important to ensure the correct planning and preparation is completed before any data collection can be done to ensure that all surveyors understand and are aware what the goals are.

This component will look at the creation and implementation of an annual survey that will be monitoring nutrient levels flowing into the Pontsticill reservoir. Excess nutrient flow can have a number of consequences on water quality and can lead to eutrophication of the water bodies. This will be done through the use of software such as Mergin Maps and QGIS to collect, store and visualise the data.

3.2. Site Description

Pontsticill reservoir is a reservoir located on the border between the counties of Merthyr Tydfil and Powys in South Wales. The site is a popular location for recreational purposes such as hiking and dog walking as well as a sailing club that utilise the reservoir. A number of different species have been identified to utilise the reservoir such as Canadian geese (NBN Atlas, 2024) as well as a wide range of fish species such as pike, carp and brown trout as documented by the Merthyr Tydfil Angling Alliance (MTAA, 2025).

A large number of hillsides to the east of the reservoir are utilised as farmland where sheep are regularly grazed throughout the year. On the West is mostly forestry managed by Natural Resources Wales (NRW). There are a number of small streams which run through these areas that flow directly into the reservoir. Sheep farming has been shown to have to potential to cause nutrient runoff into waterways (Cournane et al., 2011) so it is important to monitor these waterways to ensure that nutrient run off is kept to a manageable level.

This site is almost completely open to the public with a number of footpaths that follow the shoreline of the entire reservoir. There are certain areas closed off for safety reasons such as areas utilised by Welsh Water but these areas are easily avoidable and don't impact potential sampling areas. There are a number of signs which explicitly state not to enter the reservoir so any sampling must comply with these guidelines.

3.3. Methodology

The aim is to create a repeatable survey to measure nutrient runoff within the streams around the reservoir. A method for identifying and recording potential sampling sites must be established before the surveys can be complete. Potential sampling sites must be accessible as well as have a consistent water flow to test. In order to locate and map potential sampling sites, margin maps can be used. This program allows for the mapping of features as well as inputting data relating to these features. A walkthrough of the site will be conducted, noting potential sampling stations on margin maps that meet the requirements of the survey. As this survey is designed to be repeatable, margin maps does not need to be utilised every time the survey is conducted. It will be utilised to plan out sample locations then future surveys can use an attribute table to fill in the details. An attribute table was created to input field data (Figure 19).

Station ID	Accessible by footpath	Estimated stream width (cm)	Estimated stream depth (cm)	Additional notes	Date/Time	Surveyor Initials
Integer	Y/N	Decimal	Decimal	TextString (500)	Date/Time	Text String (3)

Figure 19 Headings of attribute table and format of data for the survey stations margin maps project

Once sample sites have been identified and mapped using margin maps, the survey outline can be designed. A number of parameters will need to be noted down when completing the survey. The first set of notes that need to be taken is the survey records. This involves noting the station ID of the site being surveyed, the date/time the survey was taken and the initials of the surveyor. There are required in order to record the basic information of when and by who the survey was conducted by.

		Records			Nutrient Readings		Site Variables		
Station ID	Coordinates	Date/Time	Surveyor Initials	Survey Protocol	Phosphates	Nitrates	Precipitation in last 3 days	Water Flowing	Notes/Comments
Integer	Latitude Longitude	DD/MM/YYYY HH:MM	TextString (3)	Decimal	mg/l	mg/l	Y/N	Y/N	TextString (300)

Figure 20 Headings of attribute table and format of data for nutrient testing

Survey protocols are the procedures that must be followed in order to carry out the survey correctly. A copy of this should be provided to anyone conducting the survey to ensure it even if someone hasn't done the survey before, there are instructions on how to complete it. Depending on the kind of survey there may be multiple methods and so it should be listed which protocol was used.

As the aim is to measure nutrient runoff within the streams, the 2 key parameters that will be measured is nitrates and phosphates. These will be measured on site using chemical testing kits. The metrics will be measured in mg/l which will be stored as a decimal as this format will better represent the data collected. The final data inputs cover site variables. These include weather conditions, whether there was flowing water and any additional notes taken during the survey.

3.4. Results

While in the field data collection did occur during this project, for a number of reasons such as time constraints and suitability. This data was not able to be utilised for this project. Data collected from the initial survey will be included in this report as evidence of fieldwork (Appendix 1). However, any data going forward in this component is example data for the purpose of demonstrating the processing of the data.

Sampling station locations were determined based on site visits. These site locations were mapped via mergin maps based on accessibility. The data was mapped in the form of points as this best represents the single sampling location rather than lines or polygons. Data of each site was noted in mergin maps which was then synced with a QGIS project in order to visualise the data (Figure 21, 22).

Station ID	Accessible by footpath	Stream width	Stream depth	Additional Notes	Date/Time	Surveyor Initials
1	true	110	30	NULL	08/05/2026 13:55:36 (UTC)	IJ
2	true	80	20	NULL	08/05/2026 14:07:29 (UTC)	IJ
3	true	90	25	NULL	08/05/2026 14:19:48 (UTC)	IJ
4	true	90	30	NULL	08/05/2026 14:35:17 (UTC)	IJ
5	NULL	75	25	NULL	08/05/2026 14:56:43 (UTC)	IJ
6	true	50	10	NULL	08/05/2026 15:03:06 (UTC)	IJ
7	true	65	20	NULL	08/05/2026 15:22:02 (UTC)	IJ
8	true	90	40	NULL	08/05/2026 15:43:21 (UTC)	IJ

Figure 21 Attribute table containing the data collected via mergin maps

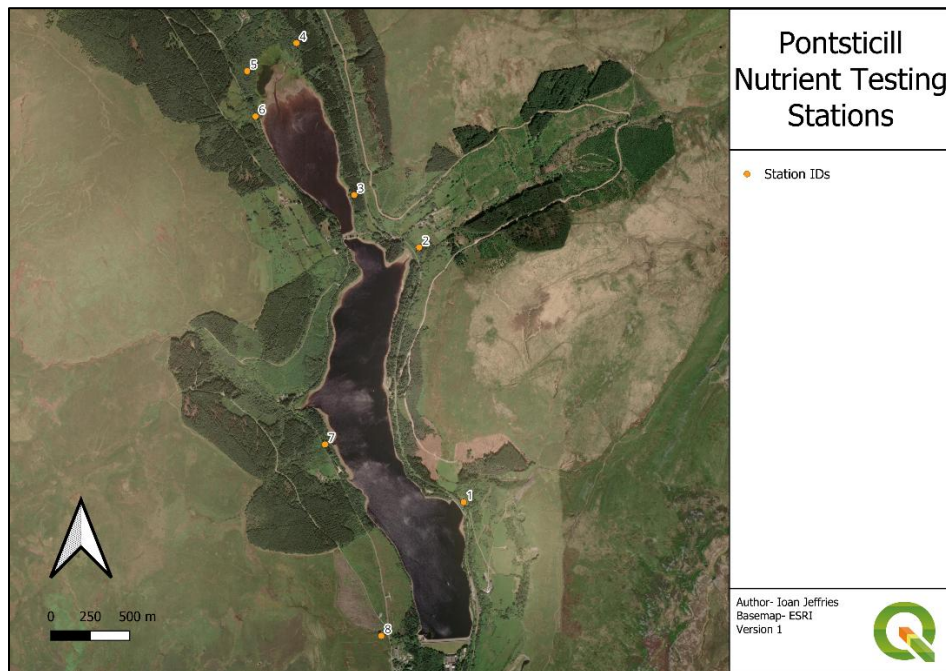


Figure 22 Map of the selected sampling stations

With the site locations selected, sampling at each of the stations can be conducted in line with the parameters set out in (Figure 20). This data was then inputted into QGIS and a map created to visualise the nutrient scores for each sample site (Figure 23)

Station ID	Records			Survey Protocol	Nutrient Readings		Site Variables		
	Coordinates		Date/Time		Phosphates	Nitrates	Precipitation in last 3 days	Water Flowing	Notes/Comments
Integer	Latitude	Longitude	DD/MM/YYYY	TextString (3)	Decimal	mg/l	mg/l	Y/N	TextString (300)
1	51.805769	3.362228	10/05/2026	IJ	1.1	7	5 Y	Y	
2	51.819939	3.366344	10/05/2026	IJ	1.1	9	4 Y	Y	
3	51.828097	3.373878	10/05/2026	IJ	1.1	7	4 Y	Y	
4	51.831917	3.377231	10/05/2026	IJ	1.1	6	5 Y	Y	
5	51.831625	3.38135	10/05/2026	IJ	1.1	6	3 Y	Y	
6	51.828625	3.381556	10/05/2026	IJ	1.1	7	4 Y	Y	
7	51.810811	3.377739	10/05/2026	IJ	1.1	5	3 Y	Y	
8	51.798136	3.369256	10/05/2026	IJ	1.1	6	3 Y	Y	

Figure 23 Example data for the Pontsticill nutrient survey

4. Conclusion

GIS and remote sensing are both powerful tools which when utilised correctly, can allow for the continuous monitoring, assessing and visualisation of a wide range of factors. These tools can fulfil a wide range of capabilities that can help with environmental conservation threat and pressure mapping. An example of GIS and remote sensing being used to protect habitats is the use of GIS to map the Great Barrier Reef and its bleaching extent. Sea surface temperature data and GIS modelling allowed researchers to predict and map which areas were most vulnerable to coral bleaching (Berkelmans and Oliver, 1999).

Another example of how GIS and remote sensing is utilised is in protecting areas such as the Amazon rain forest. Programs such as Monitoring of the Andes Amazon (MAAP) utilise data such as Sentinel-2s spectral imagery to identify large areas of removed foliage to locate illegal operations such as tree felling and mining operations (MAAP, 2024). The frequent imagery taken by Sentinel-2 allows for consistent monitoring of these protected areas.

It is important however to consider that remote sensing can only identify so much. As previously discussed it is important to incorporate many aspects including on the ground surveys in order to obtain accurate and reliable data that can be utilised.

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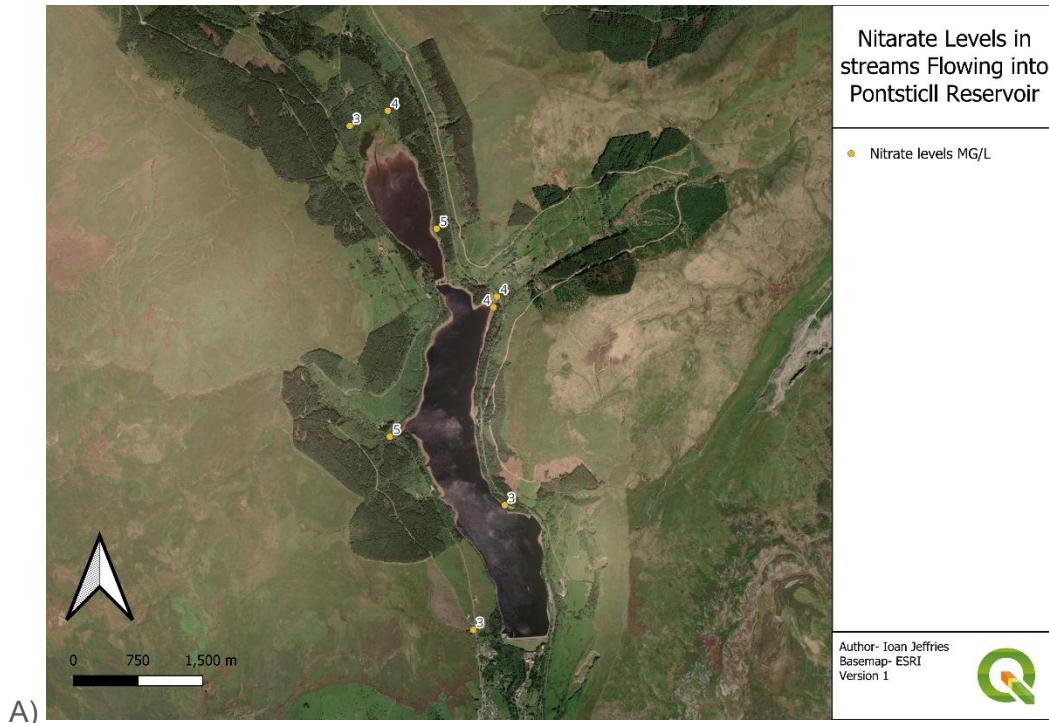
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6. Appendix

Appendix 1 A) Map of nitrate levels measured flowing into Pontsticill Reservoir. B) A) Map of nitrate levels measured flowing into Pontsticill Reservoir. C) Attribute table associated with appendix A and B.



	fid	Station ID	DateTime	Phos_mg/l	Nitr_mg/l	Rain_Last3days	Notes
1	1	1	05/05/2026 17:...	7	3	true	NULL
2	2	2	05/05/2026 17:...	9	4	true	NULL
3	3	3	05/05/2026 17:...	8	4	true	NULL
4	4	4	05/05/2026 17:...	9	5	true	NULL
5	5	5	05/05/2026 18:...	8	4	true	NULL
6	6	6	05/05/2026 18:...	8	3	true	NULL
7	7	7	05/05/2026 18:...	9	5	true	NULL
C) 8	8	8	05/05/2026 19:...	7	3	true	NULL