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A Survey Protocol for Creating an
Isonomic Map to Spatially Explore
Patterns in Tree Mortality on
Minespoil in South Wales

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2055 words

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1 Introduction

1.1 Rationale

Wales has an industrial legacy from coal mining, with 40% of the UK's coal tips located in the country; of these, 13.3% are classed as category C or D, meaning at a high risk of collapse (Welsh Government, 2021). Most coal tips were officially 'reclaimed' by the National Coal Board in the 1960s-80s, but in practice the process (capping and sowing with grass and clover species) left these sites in a grassy but actively degrading state (Plampling et al., 2009). Little money is therefore available for such areas (Haigh, 2000), but new government estimates put the necessary costs to stabilise the tips in a world increasingly affected by climate change at up to £600m in the next 10 to 15 years (BBC, 2021).

As such, the Cradle For Nature Project was established in 1990 on a site on Varteg Hill, near Blaenavon, that aimed to use trees to reclaim a section of minespoil (Plampling et al., 2009). Trees have the capability to remedy many of the issues minespoil poses: their roots provide slope stabilisation, they improve hydrology (both retention and infiltration rates), they provide humic inputs to begin healthy pedogenesis, they 'lock up' heavy metals, and they provide a nursery for other species to develop (Walker et al., 2007; Desai et al., 2019). However, the very issues they can remediate also inhibit their growth on minespoil, and so the Project studies methods to improve germination success and survival rates (Haigh, 2008).

The plot under examination ('Mike's Plot') was planted in 2007 by the University of Wales, Trinity St David (UWTSD; then Swansea Metropolitan University). 400 trees – primarily a mix of oak (*Quercus petraea*), alder (*Alnus glutinosa*) and birches (*Betula pendula* and *B. pubescens*), with some others mixed in – were notch planted into a fenced-off section of approximately 120m², and annual growth measured every October by means of height and diameter at base height. Growth success has been limited, with various possible reasons suggested; however, to date no real explanations for the mortality patterns seen have emerged (Plampling et al., 2009; Cradle For Nature, 2018). This proposal suggests that a microtopographical survey might reveal patterns in the phytosociological links between successful vegetation on site, and possibly explain the success – or lack thereof – of the trees.

1.2 The Site

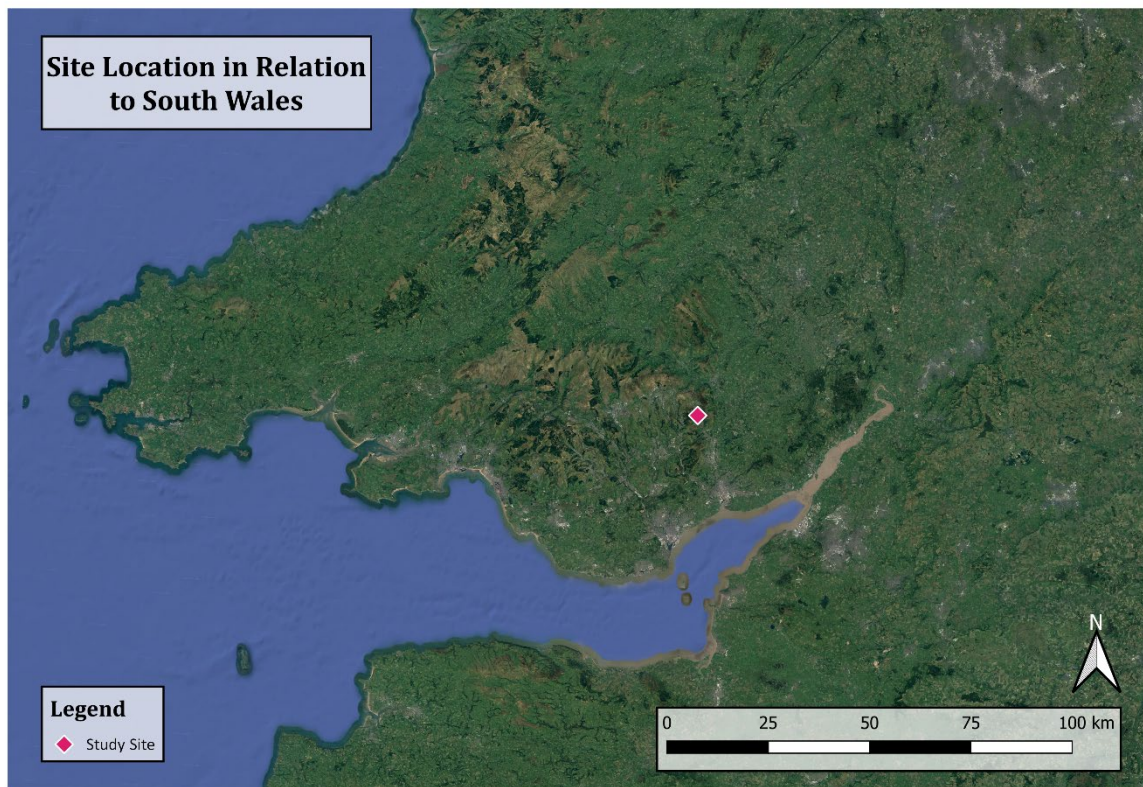


Figure 1-1. Map of the study site in relation to South Wales

Formerly part of the Waun Hos cyn Extension Mine and closed in 1963 (Haigh, 1995), the site at Varteg (325691, 205778; see Figure 1-1) was formerly reclaimed in 1970. Tree planting began in 1990 (Plamping et al., 2009). The particular site in question, “Mike’s Plot”, was planted in four blocks labelled A-D (see Figure 1-2; trees shown are the surviving organisms as of 2017). The site sits at around 380ft above sea level, and is subject to regular adverse weather, with an average annual precipitation of 114.5mm (World Weather Online, 2021). Figure 1-2 displays the wind rose for Varteg Hill, taken from Meteoblue.

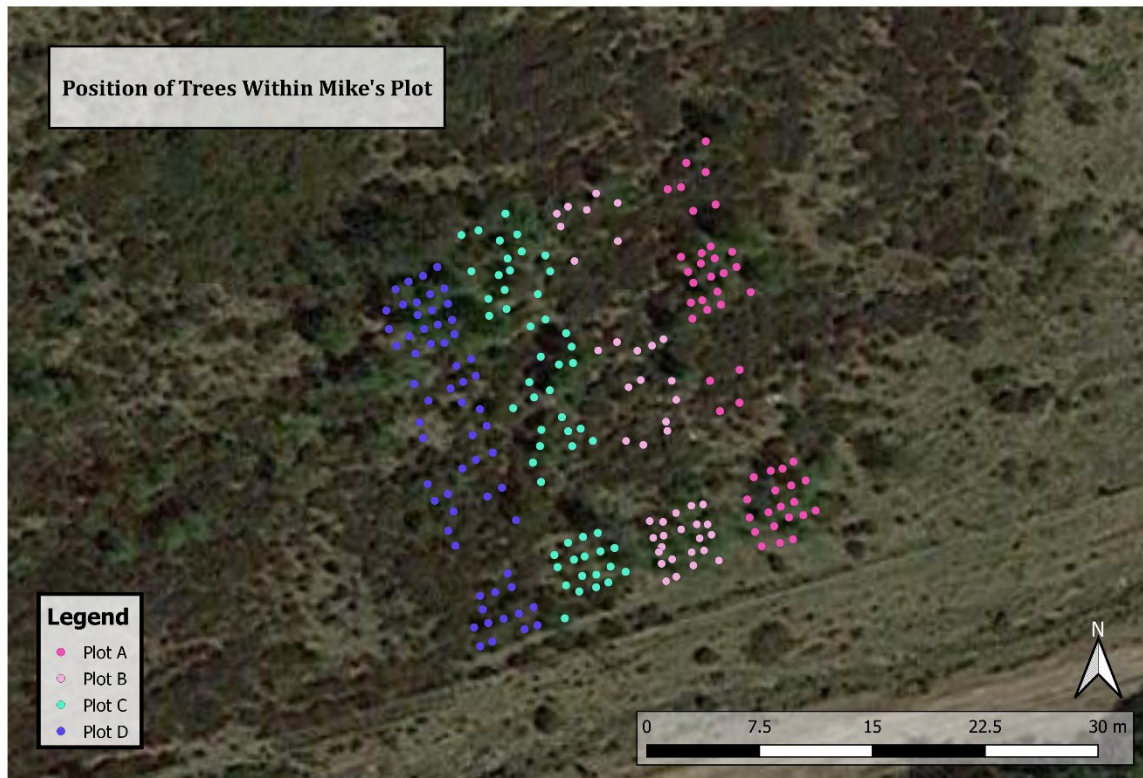


Figure 1-2. Map of Mike's Plot, displaying planted trees in blocks

The soils of the site are highly heterogenous. In 2012, UWTSD examined the bulk density of the soils taken from 20 samples across the site, and found the results ranged from 1.89 – 3.01mg/cm³ (average 2.53mg/cm³). This compaction is reflected in the poor drainage of the area. In the same year, heavy metal concentrations were also sampled from four plots, and while manganese and magnesium were found to be significantly higher than cadmium, copper and nickel across the board, quantities varied enormously (Garate, 2016). The soils are also deeply furrowed, owing to a farmer ploughing the site prior to planting in a bid to loosen them; instead, this has resulted in dramatic long-term change to the microtopography of the site (Plamping et al., 2009).

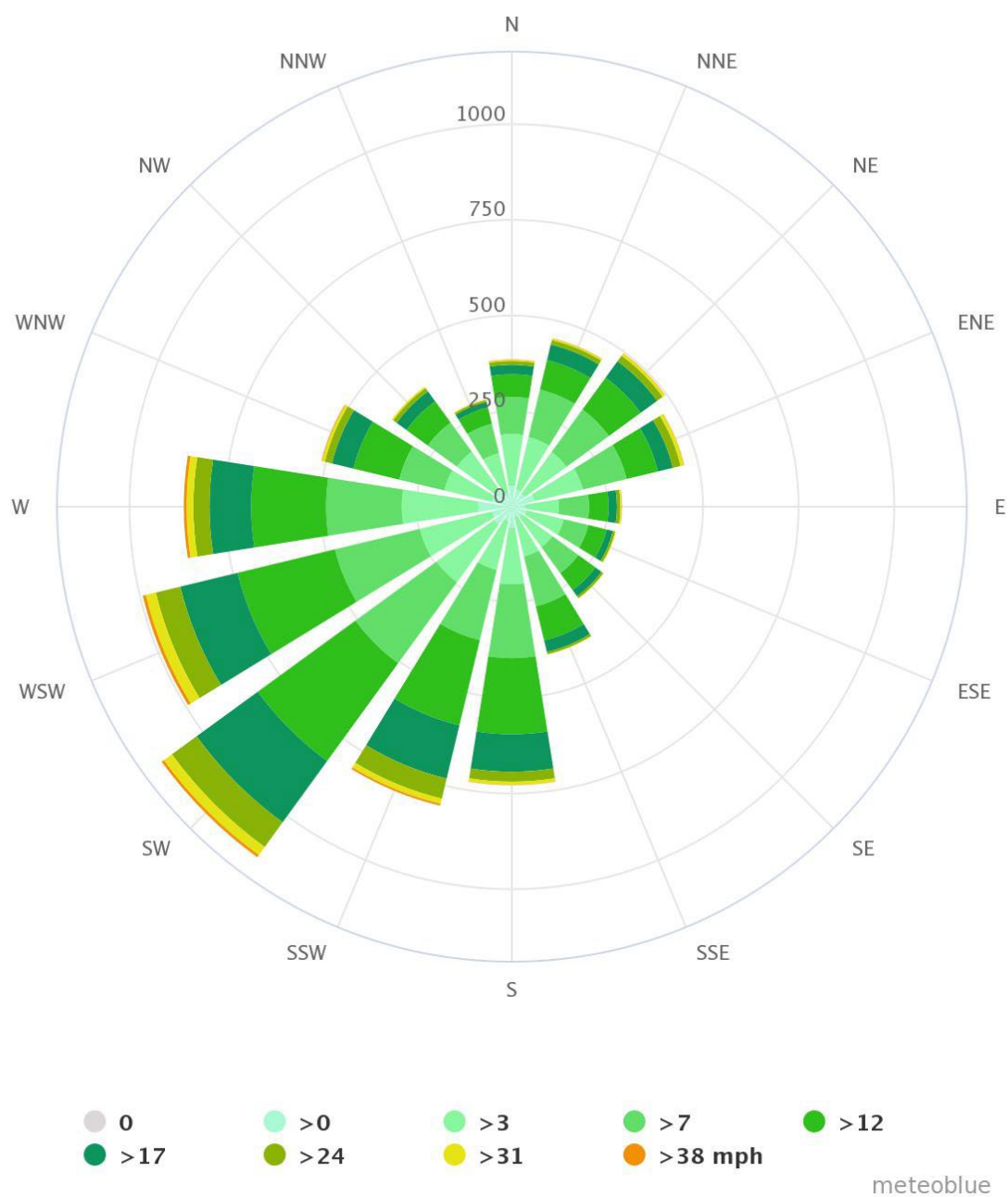


Figure 1-3. Wind Rose for Varteg Hill. From (Meteoblue, 2021)

2 Research Aims and Objectives

2.1 Research Aims

The aims of this research are to explore potential reasons for the patterns in mortality rates in Mike's Plot. The data set monitoring the trees runs from 2007 to 2019, and includes the years in which trees died, allowing for temporal patterns to be analysed alongside spatial ones. There is a strong body of literature linking features of microtopography to germination and phytosociological patterns (Harper et al., 1965; Johnson, 1972; Turkington & Harper, 1979; Collins et al., 1982; Vivian-Smith, 1997; Bledsoe & Shear, 2000; Werner & Zedler, 2002; Brewer & Whelan, 2003; Moser et al., 2007; Montané et al., 2011), so this research seeks to explore this avenue.

2.2 Research Questions

The research poses the following questions:

- 1) Do microtopographical features of the site correlate with plant distributions?
- 2) Are phytosociological relationships revealed by producing such a map?
- 3) Do these features and/or relationships help to explain the patterns in mortality rates of the trees?

2.3 Justification

The link between phytosociological relationships and microtopographical factors is well-established, from trees (Barry & Kroll, 1999; Manov & Kut'yavin, 2021) to grasses (Turkington & Harper, 1979) and even earthworms (Johnson, 1972). Harper et al. (1965) found that microtopography affects the germination success of various different plant species. Sedge meadow soils support higher species richness with rougher microtopography (Werner & Zedler, 2002) – ongoing sedimentation reduces heterogeneity, leading to loss/reduction of tussocks of *Carex stricta*. Other native species facilitated by the tussocks resultingly reduce in occurrence.

There is a strong link, also, with wetter sites (which Varteg is), seemingly owing to the fine-scale influence of altered hydrology. Multiple studies have found that rougher topography increases species richness - Bledsoe & Shear (2000) found rougher microtopography aids

wetland restoration as it often increases water retention. Moser et al. (2007) found that disking (roughing the surface microtopography across most of the site) created the best levels of species richness and most closely mimicked a natural wetland site, preventing the predominance of a few generalist species.

Woody species in wetlands also see impacts from microtopography on their germination success (Collins et al., 1982; Huenneke & Sharitz, 1986; Titus, 1990). And even microtopographic variation of a few centimetres in relief affects species richness and abundance in wetland plant communities (Vivian-Smith, 1997).

However, no research of this type seems to exist for minespoil.

3 Proposed Protocol

3.1 Protocol Outline

The site measures approximately 25m x 25m, with each of the four plots roughly 5m wide (Figure 1-1). 100 trees were planted in each, with a gap between each block of 25. As this study is specifically focused on finding links with tree mortality, the grid of transects and quadrats will be laid out to sample the areas where tree planting specifically occurred; Figure 3-1 shows their locations.

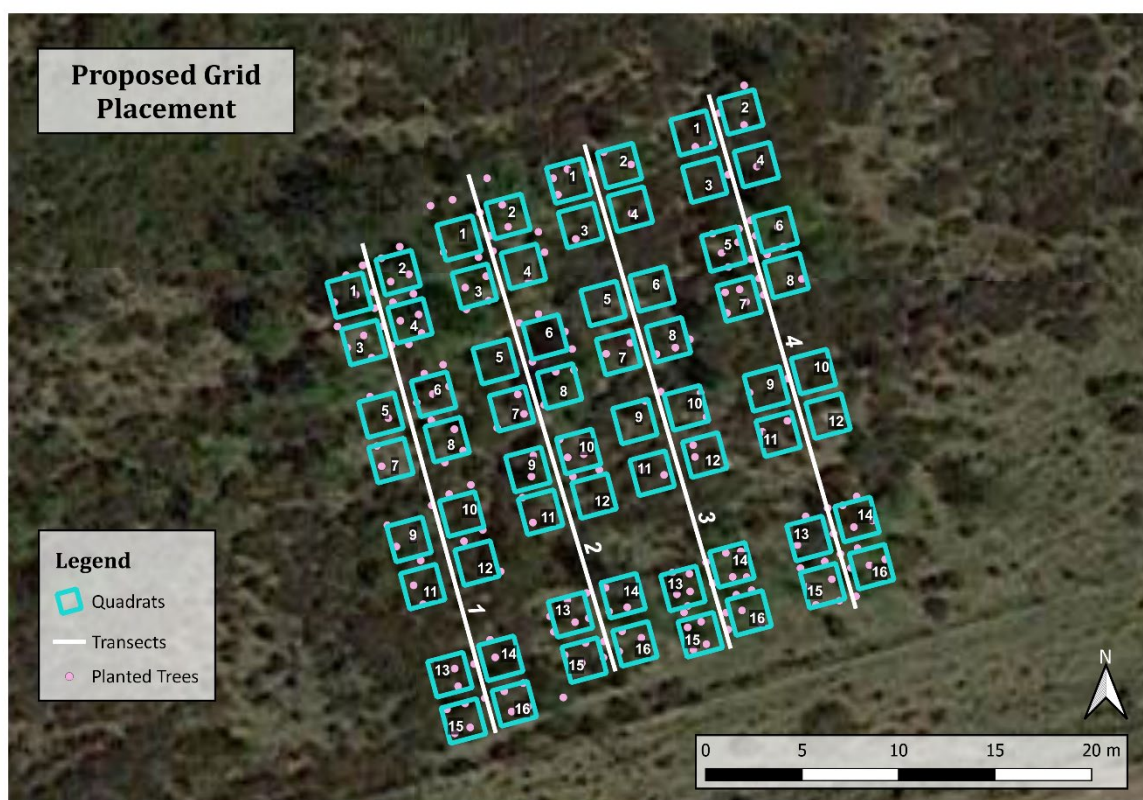


Figure 3-1. Grid position of transects and quadrats relative to planted trees.

Quadrats will be 2m². A transect will bisect each of the planting blocks, and 16 quadrats will be placed along each for a total of 64.

Vegetation species rooted within each quadrat will be identified and visually estimated for percentage cover. For cover of less than 15%, figures will be estimated in 1% increments; over 15% they will be estimated in 5% increments. Non-plant surface features (e.g. logs, rocks, etc) will be measured the same way. Each planted tree in the quadrat will be recorded (these are pre-tagged).

Elevation will be measured using Structure-from-Motion with Multi-View Stereo (SfM-MVS) photogrammetric techniques, whereby ~34 oblique convergent 18 megapixel images will be taken around each quadrat from viewpoints ~1.5m above ground to avoid the ‘doming effect’ (James et al., 2017). These will then be imported into Agisoft Photoscan Professional 1.2.5 and SfM algorithms implemented; see Smith & Warburton (2018) for further details.

A soil sample of 50g will be taken from within each quadrat. Finally, to measure water table depth 2.4mm gauge steel welding rods will be used. These will be driven to either refusal or 80cm depth, one in each quadrat, and exchanged for new ones after no less than 4 weeks at a time. Upon removal the rods will be examined for the below-surface level at which there is no oxidation – this will be taken as the water table height.

All sampling will be done between April and November, to account for phenological variables and fluctuating water levels (apart from soil sampling, which will be done once). Data will be used to construct isonomic maps, showing species distribution and microtopography. The existing data set with tree mortality will be overlaid in QGIS. These maps will answer all three research questions.

3.2 Evaluation

Most studies that use grids and isonomic maps use straight transects and simply space quadrats along those at regular intervals to sample (Kent & Coker, 2012). Brewer & Whelan (2003) used a grid of transects and quadrats to create an isonome map of a sand dune system to track fine-scale distributions of three dominant species, which replicated a study from decades before; it revealed that there were phytosociological associations between dominant species in 1941, that were absent post-sand mining. Montané et al. (2011) used a grid to produce isonomic maps displaying spatial heterogeneity and how that affects vegetation patterns. Barry & Kroll (1999) specifically used a grid to examine the phytosociological relationships between trees, while Turkington & Harper (1979) used theirs to study pasture grasses in North Wales. Even beyond plant studies, Johnson (1972) used a 10m x 10m grid to sample soil for earthworms. In this instance, regular spacing would place quadrats into areas the trees were never planted, so the methodology has been adapted to more deliberate placement.

Moser et al. (2007) instead used a circular sampling design of four nested transects (see Figure 3-2). The multiscale transects remove directional bias, such as orientation of sunlight, direction of hydrological flows, wind, etc). It also covers a more limited spatial extent, and so reflects more localised conditions; this is appropriate for the site, which is relatively small. However, Moser et al. (2007) were looking to compare microtopographic data with wetland indicator species rather than create an isonomic map; as such, a grid is better suited to this study.

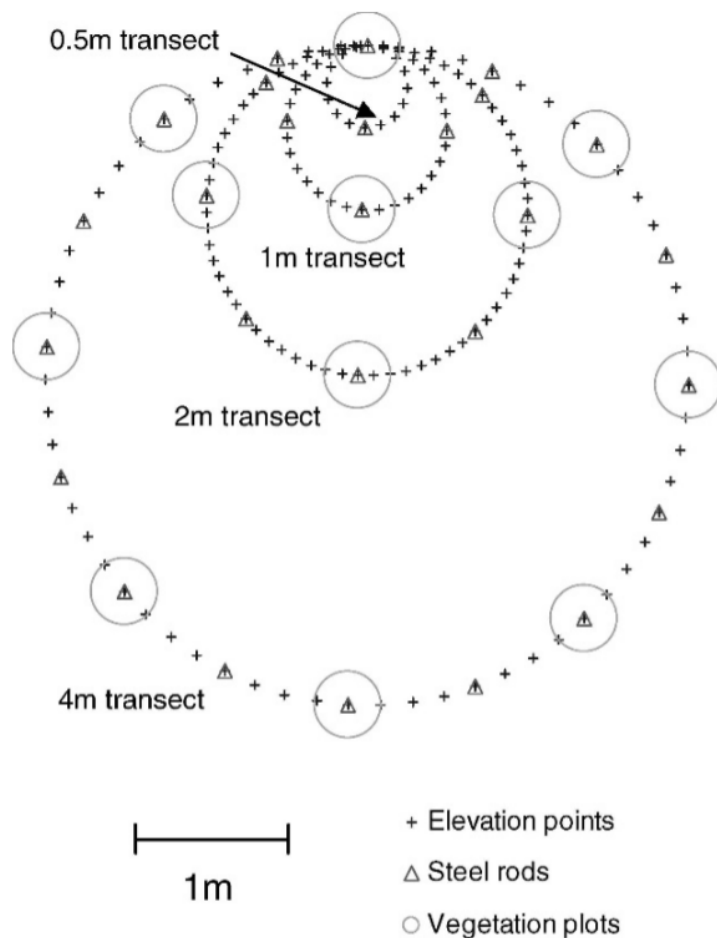


Figure 3-2. Multiscale transects. Reproduced from Moser et al. (2007)

There are various options for which factors to measure for microtopography. Johnson (1972)'s earthworm study chose six abiotic factors to sample: soil moisture, pH, porosity, bulk density, organic carbon and texture. Most agricultural studies into microtopography focus on erosional features to quantify it (Moser et al., 2007); and Moser et al. (2007) themselves included a measure of wetland indicator species value. These factors must be chosen with the

research questions (and the site conditions) in mind. Here, the site is known for heterogenous and dense soil, for compacted hydrology, and for pronounced furrows.

3.3 Existing Protocols

Generally isonomes are not a common tool; however, the standard method for measuring topography is generally LiDAR. Even though this research is proposing fine-scale measuring, 10cm LiDAR produces reasonably accurate DEMs that can display differences in elevation of as little as 2cm, although with some errors (Smith, 2013). However, data at this resolution is not currently available in Wales; the closest is 25cm, which is not sufficient for these scales (Natural Resources Wales, 2015).

SfM and Unmanned Aerial Vehicle Photogrammetry (UAVP) technologies are increasingly being used, with both reporting extremely low error thresholds (Roosevelt, 2015; Smith & Warburton, 2018). SfM was eventually chosen for the fine-scale grain of the results (a 5mm DEM), and enabled by the small size of the overall site.

4 Anticipated Data

4.1 Data Storage

Data will be immediately transferred from recording sheets (see Appendix A for example) to a backed-up master copy, and checked for entry errors. Ultimately, the data obtained will primarily be for use in map creation; as such, while the raw data can be kept in table form, much of it will be formatted in files for use in GIS programs such as QGIS. This might include .CSV files, shapefiles, etc. The maps themselves can be created and stored as JPEGs or PNGs.

Data gathered should be shared with the Cradle For Nature Project, to supplement their ongoing research on the site.

4.2 Analysis

Species richness (S) per quadrat will be calculated by a taxon count, and a taxon-sampling curve used to standardise the data based on 50 randomised runs (Buddle et al., 2005). The Shannon diversity index will then be used to characterise plant diversity without making assumptions about underlying distribution patterns (Kent & Coker, 2012).

Soil samples will be measured for bulk density in the lab by drying and weighing. They will also be analysed for heavy metal content.

Microtopographic images will be ultimately converted into a 5mm DEM. All data will then be combined to create isonomic maps in QGIS, and the existing tree mortality data added.

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6 Appendix A

6.1 Example Datasheet

Varteg Isonome Datasheet

Date	
Name of Surveyor	

**Note: take GPS reading at the centre of each quadrat*

Transect Number:	Quadrat Number:	GPS:
Species:	% Cover	

Other Objects	%Cover
Rocks	
Logs/Wood	
Other (specify)	

Planted Trees	
Tag Number	Species

Soil Sample GPS	
Water Rod GPS	