Appendix 2

Optimum Shelter Belts

How to Guide

Monitoring the characteristics of your Optimum Shelter Belt

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Introduction

The role of porosity in shelterbelts/windbreaks (hereafter referred to as shelterbelts) is well recognised with numerous studies exploring how a change in porosity affects the qualities of the associated shelterbelt[1,2]. Many projects, such as Nelmes[3], attempt to explore this relationship through models in wind tunnels, subsequently extrapolating their calculations to be applicable to in-field scenarios. Utilising wind tunnel models allows for greater flexibility in exploring characteristics that can summarise shelterbelt qualities, thus reducing workloads when taking in-field assessments. Nelmes identified a single value, S, which requires only a handful of measurement to provide a general view of the aerodynamic impact of any shelterbelt. Specifically, S expresses the relationship between upstream velocity and downstream velocity through the equation:

$$s = \sqrt{\frac{Mean\ velocity\ downsteam^2 + RMS\ velocity\ downstream^2}{Mean\ velocity\ upsteam^2 + RMS\ velocity\ upstream^2}}$$

During this work she found that S has no relationship with porosity, suggesting that the ratio of upstream and downstream wind velocity in unaffected by the amount of air that can flow through the shelterbelt. In addition Nelmes suggests that porosity has little effect on the distance over which a change in velocity is felt.

These results are in stark contrast to other studies which show that at low levels of porosity there is a large drop in velocity, but this effect is only felt over a small distance[4]. Likewise, at high porosity there is a smaller drop in velocity but over a larger area. This relationship, however, only holds for narrow shelterbelts and weakens as the shelterbelt width expands. Further work is needed to explore these differences by collecting data from in-field scenarios, testing S and its relationship to porosity, and confirming the association with porosity, velocity reduction, and area impacted. This will also help identify an optimal porosity to maximise protection effects, although this may vary between seasons.

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[1] Cleugh, H. 1998. Effects of windbreaks on airflow, microclimates and crop yields. Agroforestry Systems. 41. p55-84.
[2] Mahgoub, AO & Ghani, S. 2021. Numerical and experimental investigation of utilizing the porous media model for windbreaks CFD simulation. Sustainable Cities and Society. 65. 102648.
[3] Nelmes, S. 1999. The aerodynamic characterisation of shelterbelts. PhD Thesis. University of Oxford.
[4] Ma, R et al. 2020. A wind tunnel study of the seasonal shelter efficiency of deciduous windbreaks. American Society of Agricultural and Biological Engineers. 63(4). p913-922.

Previous work has explored the topic on seasonal variations in shelterbelt quality, however the work utilising in-field experiments and measuring porosity variation over the seasons is limited[4,5,6]. The utilisation of a mix of deciduous and evergreen species if often recommended in shelterbelt planting. This mitigates some of the seasonal porosity changes but how the ratio of species can be optimised to offer the appropriate levels of protection at different times of the year is still unclear. Similarly, pruning, thinning, and other management activities are commonly only recommended when the shelterbelt becomes too dense or for tree health issues. Knowledge and data around how different approaches to tree management in shelterbelts relate to porosity is another area that needs further research.

An additional aspect related to tree management which has yet to be explored through on-field experiments is the angle of tapering from lower to upper edges of the shelterbelt. Previous modelling experiments suggest that the shape (i.e. triangle or square face) doesn't affect the sheltering qualities of the barrier[7], however, an edging technique is common practice in commercial forestry to reduce the chance of windthrow[8], particularly at the edges of the plantations. Having a tapered edge may therefore reduce damage to the shelterbelt from strong winds, however, how to optimise this effect in shelterbelts is unknown. By measuring the angle of taper, this methodology will be able to explore if the angle of taper has an impact upon shelter quality. Similarly over longer periods when storm may occur, noting the damage caused to the shelterbelt could be related to the angle.

Finally, these protocols are developed to be used, in part, by farmers and landowners themselves. To this end, where possible they have been designed to be simple in approach and using basic equipment. Simple measurements such as tree height, however, can be done using an assortment of different methods, some of which may be more accurate than others. Previous work has compared technical methods of measuring tree height i.e. LiDAR against Clinometers[9], however there is little research into comparisons of non-technical methods. Using a Clinometer is considered a standard method of measuring tree height and will be used as a reference value. Additional methods will also be used to measure tree height for comparison, the first using a spirit level mobile app as a proxy for measuring the viewing angle, much as a dedicated clinometer would. The second approach uses a piece of A4 paper folded to create a 45 degree angle from which the height can be deduced. Details of the methods used are detailed in the protocols below.

General Approach

This methodology aims to explore these areas by:

1. Testing the relationship between porosity and S on in-field examples.
2. Capturing the link between porosity, windspeed reduction, and impacted area.
3. Identifying the temporal variation in shelterbelt porosity.

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[5] Koh, I. et al. 2014. Seasonal effectiveness of a Korean traditional deciduous windbreak in reducing wind speed. Journal of Ecology and Environment. 37(2). p91-97. http://dx.doi.org/10.5141/ecoenv.2014.011

[6] Baker, T. P. et al. 2021. Temporal, environmental, and spatial changes in the effect of windbreaks on pasture microclimate. 297. 108265. https://doi.org/10.1016/j.agrformet.2020.108265

[7] Wang, Hao, and E. S. Takle. 1997. Model-simulated influences of shelterbelt shape on wind-sheltering efficiency. Journal of Applied Meteorology. 36 (6). pp695-704. DOI:10.1175/1520-0450-36.6.695.

[8] Gardiner, B., Stacey, G. 1996. Designing Forest Edges to Improve Wind Stability. Forestry Commission. Technical Paper 16.

[9] Ganz, S., Käber, Y., Adler, P. 2019. Measuring Tree Height with Remote Sensing—A Comparison of Photogrammetric and LiDAR Data with Different Field Measurements. Forests. 10 (8). pp694. DOI: 10.3390/f10080694.

4. Exploring the impacts of different tree management strategies and tree types on seasonal porosity and other longer-term qualities.

The output of this work will allow offer greater clarity of the desired porosity for protection, which times of year this protection is at its maximum/minimum, and how management types and species selection can support this maximum/minimum protection. This can then be related to specific location climate and agricultural qualities i.e. crop disease vulnerability, livestock birthing, etc.

Protocols

Measuring optical porosity with a camera

Rationale

Optical porosity is a frequently used, low cost method of analysing the density of shelterbelts[10]. There are more detailed and vigorous approaches, such as LiDAR, are possible however the equipment is expensive and requires extensive training to use[11]. The below method describes a way of calculating the porosity without complex machinery, simply using a phone and online software. The software used has been used in other studies for this purpose and is free to access online[12].

Repeating the process across the seasons creates an understanding of how porosity and thus shelter effects change over the year, feeding into future recommendations around optimal design for maximising shelter effect at certain times of year.

Method

Take 3 identical sets of photos which capture the full height of the shelterbelt without any obstructions. Where possible try to take the photo positioned perpendicular to the shelterbelt. The photo should not be angled up or down, being perpendicular to the ground. In addition try to minimize the level of blurring or other artefacts in the photo and capture the highest resolution possible. 3 photos are required to account for any changes in opacity due to leaves moving in the wind and to provide a more accurate final value. Ensure the sky is visible through the trees and no buildings are situated directly behind the shelterbelt in the photos.

Transfer the photos to a computer and open Fiji/imageJ or visit https://ij.imjoy.io/ - will take a few minutes to load.

File > open… > select local file, then browse to where you have the photos saved and open one.

Once the photo has loaded select the rectangle on the menu and then draw the rectangle over the trees so that the top of the trees is at the top of the rectangle, and the bottom of the trees is at the bottom of the rectangle. This is to remove any excess sky or crops/pasture that would lead to an incorrect analysis.

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[10] Wu, Tonggui., Zhang, Peng., Zhang, Lei., Wang, Jingyuan., Yu, Mukui., Zhou, Xinhua., Wang, Geoff. Relationships between shelter effects and optical porosity: A meta-analysis for tree windbreaks. 2018. Agricultural and Forest Meteorology. 259. pp 75-81. https://doi.org/10.1016/j.agrformet.2018.04.013.
[11] Nowak, Maciej M., Pędziwiatr, Katarzyna., Bogawski, Paweł. Hidden gaps under the canopy: LiDAR-based detection and quantification of porosity in tree belts. 2022. Ecological Indicators. 142. 109243. https://doi.org/10.1016/j.ecolind.2022.109243.
[12] Marais, Zara E., Baker, Thomas P., A. Hunt, Mark., Mendham, Daniel. Shelterbelt species composition and age determine structure: Consequences for ecosystem services. 2022. Agriculture, Ecosystems & Environment. 329. 107884. https://doi.org/10.1016/j.agee.2022.107884.

Image > Type > 8-bit

This will convert it to a black and white-style image.

Process > binary > make binary

This will convert it to a full binary (black and white pixels only) image.

Analyze > Histogram

If a box pops up then just press continue/OK until you get to a graph. The graph will appear blank but this is just because there are only two values on the spectrum, pure black and pure white.

Click “List” on the lower left of the graph. This will provide a list of the number of pixels at each colour. 0 is the number of black pixels and 255 is the number of white pixels.

To work out the porosity:

$$\frac{No. of\ white\ pixels}{No. of\ black + No. of\ white\ pixels}$$

This gives a value for porosity between 0 (no porosity) and 1 (full porosity). To convert it to a percentage, times by 100.

Repeat for the other two photos. Once you have the 3 porosity values, add them together and divide by 3 to get an average porosity.

Repeat this methodology for a few different days in the week, aiming to capture photos in a range of light levels with cloudy and sunny backdrops. This will help remove error when calculating the number of object vs background pixels. The values of porosity under these different conditions can then be averaged.

Repeat this process for each of the 4 seasons to get an understanding of how porosity varies across the year.

Equipment

Camera (can be phone or dedicated camera)

Computer with access to internet

Additional Comments

Timings are non-critical – as long as most farms capture the seasons within a few weeks of each other.

Could be done my farmers (particularly the photo taking). They could then just email images over with dates for researcher analysis.

Measuring optical porosity with a drone

Rationale

Drones are becoming increasingly affordable and user friendly, providing another tool that can capture suitable imagery[13]. The ease with which drones allow for photo or video capture in a 3D space offers the opportunity to take picture at 90 degrees to the shelterbelt, increasing the accuracy of porosity calculations as well as allowing for images to be taken in areas where ground conditions may make it difficult to take photographs on the ground.

Method

Hover the drone at half the height of the trees (see measuring tree height for identifying this value). Position the drone so it is perpendicular to the shelterbelt and images are taken flat on (i.e. not aimed towards the sky/ground). Take a 3 second video or 3 still images.

Transfer the video/images to PC. If using video isolate 3 frames, 1 for each second, resulting in 3 still images.

Open Fiji/imageJ or visit https://ij.imjoy.io/ - will take a few minutes to load.

File > open… > select local file, then browse to where you have the photos saved and open one.

Once the photo has loaded select the rectangle on the menu and then draw the rectangle over the trees so that the top of the trees is at the top of the rectangle, and the bottom of the trees is at the bottom of the rectangle. This is to remove any excess sky or crops/pasture that would lead to an incorrect analysis.

Image > Type > 8-bit

This will convert it to a black and white-style image.

Process > binary > make binary

This will convert it to a full binary (black and white pixels only) image.

Analyze > Histogram

If a box pops up then just press continue/OK until you get to a graph. The graph will appear blank but this is just because there are only two values on the spectrum, pure black and pure white.

Click "List" on the lower left of the graph. This will provide a list of the number of pixels at each colour. 0 is the number of black pixels and 255 is the number of white pixels.

To work out the porosity:

$$\frac{No.of\ white\ pixels}{No.of\ black + No.of\ white\ pixels}$$

This gives a value for porosity between 0 (no porosity) and 1 (full porosity). To convert it to a percentage, times by 100.

Repeat for the other two photos. Once you have the 3 porosity values, add them together and divide by 3 to get an average porosity.

[13] Torresan, Chiara., Berton, Andrea., Carotenuto, Federico., Filippo Di Gennaro, Salvatore., Gioli, Beniamino., Matese, Alessandro., Miglietta, Franco., Vagnoli, Carolina., Zaldei, Alessandro., Wallace, Luke. 2017. Forestry applications of UAVs in Europe: a review. International Journal of Remote Sensing. 38 (8-10). pp 2427-2447. https://doi.org/10.1080/01431161.2016.1252477

Repeat this methodology for a few different days in the week, aiming to capture photos in a range of light levels with cloudy and sunny backdrops. This will help remove error when calculating the number of object vs background pixels. The values of porosity under these different conditions can then be averaged.

Repeat this process for each of the 4 seasons to get an understanding of how porosity varies across the year.

Equipment

Drone with camera

Computer with internet access

Additional comments

Timings are non-critical – as long as most farms capture the seasons within a few weeks of each other.

Drones would need to be flown by trained individuals, however the image analysis steps could be done by anyone.

Measuring windspeed values using anemometers

Rationale

Windspeed is the primary indicator for shelter effect of shelterbelts. Methods to measure windspeed in field vary, however, Nelmes (1999) identified a simplified measurement model for windspeed which requires fewer readings. This methodological approach will allow for testing of the model's performance in field settings, while also collecting the necessary data to associate windspeed with optical porosity.

Additional readings to those required for S will also need to be taken to validate S and provide a greater understanding of the size of shelter effect across the field.

Method

As per Nemes 1999:

The value of s is determined from a simultaneous measurement of horizontal velocity at two positions. The measuring positions are $1h$ upstream and downstream of the shelterbelt and $0.4h$ above ground level although instrument positioning is not critical. Mean and turbulent velocities must be measured at a sampling rate of not less than 0.5Hz, for a sampling period of 10 minutes. Any anemometer with a distance constant less than or equal to 2.3m can be used to measure the velocities. Either the component of horizontal magnitude perpendicular to the shelterbelt or the horizontal magnitude itself can be used to determine s without significant difference in results. To measure s, the wind direction must be within 25° of perpendicular to the shelterbelt. For most accurate evaluation, particularly for very non-uniform shelterbelts, s values should be averaged over the whole 50° sector.

In addition readings should be taken at 5, 10, 15, and 20H distance however these don't have to be simultaneous if the number of anemometers is limited. The same methodology for the S readings should be used to take these readings i.e. 0.4h height for 10 minutes.

Ideally these will be repeated near the middle of every season, resulting in 4 sets of readings per year.

Equipment Required

Anemometers (minimum of 2)

Additional Comments

Wind measurements should be taken on days that are not extremely windy, but also not extremely still.

Anyone could carry out these measurements, but given the time and equipment required a researcher may be best suited.

As access is only guaranteed on both sides of the shelterbelt for 15 sites. Of those 15 only 10 are angled roughly perpendicular to the prevailing wind, potentially limiting the number of samples that can be taken.

Measuring windspeed values using a drone

Rationale

While relatively novel, the notion of measuring windspeed via drone has been trialled in multiple scenarios[14,15,16]. This approach offers the ability to access windspeed at any 3D point in space across the shelterbelt. Current drone capabilities limit recordings to under 10 minutes and recording cannot be taken simultaneously unless multiple drones are used. Despite these limitations the potential of this method should be explored

Method

Numerous approaches could be taken to calculate the windspeed from drones[13,14,15].

The positioning of the drone to collect data should be independent of the method used to extract windspeed, however the time required at each location and the number of locations may be limited by battery availability.

Taking readings for 0.4H in height should be done at 1, 5, 10, 15, 20H distance from the shelterbelt on the leeward side.

Equipment Required

Drone

Additional Comments

Timings are non-critical, Wind measurements should be taken on days that are not extremely windy, but also not extremely still. However, since these data are of importance to other measures included in the research, they will be aligned with relevant times of day/year for key moments in these protocols such as seed germination or animal shade/shelter.

Drones would need to be flown by trained individuals.

Measuring tree height with a clinometer

Rationale

A near universal standard for measuring trees is to use a clinometer. Other options are available such as laser-based height measurers, however these are more expensive and pose additional risks for the user. Tree height is required to calculate various other values, such as the positioning of anemometers/drones. The height also plays and important role in determining the sheltering effect[17].

Method

[14] Simma, M., Mjøen, H., Boström, T. 2020. Measuring Wind Speed Using the Internal Stabilization System of a Quadrotor Drone. Drones. 4 (2). https://doi.org/10.3390/drones4020023.

[15] Thielicke, W., Hübert, W., Müller, U., Eggert, M., and Wilhelm, P. 2021. Towards accurate and practical drone-based wind measurements with an ultrasonic anemometer. Atmospheric Measurement Techniques. 14 (2). pp 1303-1318. https://doi.org/10.5194/amt-14-1303-2021.

[16] Crowe, D.; Pamula, R.; Cheung, H.Y.; De Wekker, S.F.J. 2020. Two Supervised Machine Learning Approaches for Wind Velocity Estimation Using Multi-Rotor Copter Attitude Measurements. Sensors. 20 (19). 5638. https://doi.org/10.3390/s20195638.

[17] Zhou, X.H., Brandle, J.R., Mize, C.W, Tackle, E.S. 2005. Three-dimensional aerodynamic structure of a tree shelterbelt: Definition, characterization and working models. Agroforestry Systems. 63. pp133-147. https://doi.org/10.1007/s10457-004-3147-5.

Place a tape measure in the middle of the windbreak (i.e. if 5m deep then place at 2.5m). with the tape measure, walk in a perpendicular line out into the field until you can comfortably look up and see the top of the tree line. Raise the clinometer to your eye and match the line/site with the top of the treeline (use an average of the treeline, not an individual tree). Note the percentage measurement on the clinometer and the distance on the tape measure.

The height of the treeline can be calculated via

$$Height\ of\ shelterbelt = Distance\ from\ shelterbelt * \left(\frac{Percentage}{100}\right) + Height\ of\ eye\ level$$

Repeat for 5 sections along the shelterbelt to get an average height.

A single reading should suffice for each year.

Required Equipment

Tape measure (10m+)

Clinometer

Additional Comments

This is not time critical and can be done at any time of year.

Anyone can complete this work.

Measuring tree height with a spirit level mobile app

Rationale

Similar in method to the Clinometer, a sprit level mobile app aims to measure the angle of viewing. This approach is of interest as mobile phones are a common item that could replace the role of a dedicated tool (clinometer), reducing cost and equipment for surveyors.

Method

Following the protocol described by Gabriel Henry[18]. Download a spirit level app to the smartphone. Place a tape measure in the middle of the windbreak (i.e. if 5m deep then place at 2.5m). with the tape measure, walk in a perpendicular line out into the field until you can comfortably look up and see the top of the tree line. Hold the phone up to one eye so that you are looking along the phone to the top of the tree line (use an average of the treeline, not an individual tree) and take a note of the angle shown on the spirit level. It may be preferable to get an app which allows you to “pause” the measurement to make reading easier.

The height of the treeline can be calculated via

$$Height\ of\ shelterbelt = \tan(angle) * Distance\ to\ tree + Height\ to\ eye$$

Repeat for 5 sections along the shelterbelt to get an average height.

A single reading should suffice for each year.

[18] https://gabrielhemery.com/how-to-calculate-tree-height-using-a-smartphone/

Required Equipment

Tape measure (10m+)

Smartphone with spirit level app

Additional Comments

This is not time critical and can be done at any time of year.

Anyone can complete this work.

Measuring tree height with a piece of paper

Rationale

Another simple method of measuring tree height is using a paper folded to make a right angle. This eliminated the requirement for a mobile phone or dedicated device i.e. clinometer, however, also requires a clear space around the tree in order to stand at the correct distance. As such this approach wouldn't be effective in a woodland setting, however for this scenario with fields surrounding the shelterbelt there should be little to no obstructions allowing the required distance to be measured easily.

Method

Based on the protocol described on WikiHow[19]. Fold a piece of A4 paper to create a right angle where you can look along the hypotenuse. Place a tape measure in the middle of the windbreak (i.e. if 5m deep then place at 2.5m). With the tape measure, walk in a perpendicular line out into the field until you can look along the hypotenuse, with the bottom of the triangle parallel to the ground, and see the top of the tree line (use an average of the treeline, not an individual tree).

The height of the treeline can be calculated via

$$Height\ of\ shelterbelt = Distance\ to\ tree + Height\ to\ eye$$

Repeat for 5 sections along the shelterbelt to get an average height.

A single reading should suffice for each year.

Required Equipment

Tape measure (10m+)

Piece of A4 paper

Additional Comments

This is not time critical and can be done at any time of year.

Anyone can complete this work.

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[19] https://www.wikihow.com/Measure-the-Height-of-a-Tree#Using-a-Piece-of-Paper

Measuring shelterbelt profile

Rational

Shelterbelt profile is unlikely to impact the sheltering effect itself, however a gently sloping profile is frequently recommended in traditional forestry to reduce windthrow. By measuring the slope profile the aim is to identify any correlation between windfall/damage and slope profile. This will require longer-term monitoring of the shelterbelt with particular focus at times of extreme wind.

Method

There are two possible angles to measure depending on the shelterbelt design. The first assumes that a single tree defined the edge of the shelterbelt. In this case, using a clinometer stand at the base of the furthest outreach of the canopy base and point the clinometer to the top of tree (orange line on Figure 1). If the top cannot be seen then estimate where the top of the tree would be. Repeat this at each point that a height reading is taken.

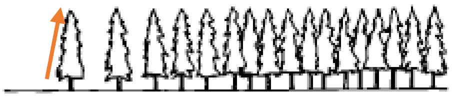

Figure 1. Diagram modified from Gardiner & Stacey, 1996.

The second design uses multiple rows of the trees at an increasing height until the top of the shelterbelt is reached. In this scenario, out from the smallest tree until you can look across the tree tops up to the highest point (orange line on Figure 2). Use the clinometer to measure this angle. Repeat this at each points that a height reading is taken.

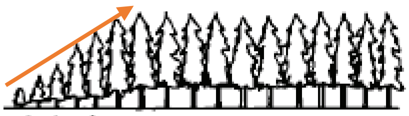

Figure 2. Diagram modified from Gardiner & Stacey, 1996.

Equipment Required

Clinometer

Additional Comments

This is not time critical and can be done at any time of year.

Anyone can complete this work.

Measuring shelterbelt depth

Rational

Shelterbelt depth is required to measure height and also adds to the visual understanding of shelterbelt characteristics that may impact the sheltering effect[16].

Method

If access to both sides of the shelterbelt is possible with the ability to move through the undergrowth, then place one end of the tape measure on the leeward side at the point where the canopy reaches out the furthest. Take the tape measure through the understory of the shelterbelt and place the end at the point where the canopy reaches out the furthest. Note the distance on the tape measure. Repeat this at least 3 more times along the shelterbelt to get an average width.

Equipment

Tape measure (10m+)

Additional Comments

This is not time critical and can be done at any time of year.

Anyone can complete this work.

Measuring species ratio

Rational

There is likely to be seasonal variation in porosity, however this will be impacted by the ratio of evergreen in the shelterbelt. By categorising the ratio of deciduous to evergreens, the species mix can be related to optical porosity and windspeed, feeding into the future recommendations for shelterbelt planting.

Method

If known from planting then:

$$\frac{Number\ of\ decidious\ trees}{Number\ of\ evergreen\ trees}$$

The greater the number is above one, the more deciduous species are present. The smaller the number is to zero, the greater the dominance of evergreens.

If the species planted and ratio isn't already known, then measurements will have to be taken. Walk along a 20m stretch of the leeward side of the shelterbelt and tally the number of deciduous and evergreen trees visible. Do the same for the windward side. If time allows then repeat these steps for 2 additional sections of the shelterbelt. The results can then be entered into the equation.

Equipment Required

Notebook, pen, calculator

Additional Comments

Timings are non-critical.

Anyone can carry out these measurements.

Data Analysis

Variables

For each shelterbelt:

- Windspeeds at:
    - Windward
        - 1H distance, 0.4H height
    - Leeward
        - 1H distance, 0.4H height
        - 5H distance, 0.4H height
        - 10H distance, 0.4H height
        - 15H distance, 0.4H height
        - 20H distance, 0.4H height
- Porosity – 4 readings a year with dates, averaged from multiple repeats.
- Tree height – 3 values per year (3 different methods)
- Shelterbelt Profile – 1 value per year
- Shelterbelt depth – 1 value per year
- Species Ratio – 1 value

Calculated Variables

D70

Plotting the Windspeeds from 1H, 5H, 10H etc. up to 20H will provide a relationship between windspeed and distance for a specific porosity. An appropriate equation should be identified to describe this relationship. This equation can then be utilised to calculate 70% of the velocity measured at 1H on the windward side (or whichever value was taken as a representation of this).

This can be repeated for each site allowing for D70 and velocity relationship equations to be calculated for different porosities.

Relative windspeed reduction

$$\frac{Windspeed\ at\ Leeward}{Windspeed\ at\ Winward}$$

S

$$s = \sqrt{\frac{Mean\ velocity\ downsteam^2 + RMS\ velocity\ downstream^2}{Mean\ velocity\ upsteam^2 + RMS\ velocity\ upstream^2}}$$

Plots and analysis

- Plot Porosity against D70 – calculate correlation co-efficient
- Plot Porosity against windspeed reduction – calculate correlation co-efficient
- Plot porosity against S – calculate correlation co-efficient
- Plot Porosity for each season – ANOVA with seasons as the group
- Plot Porosity for each season with an additional grouping of species ratio