Wood density determination in *Picea sitchensis* using computerised tomography: how do density measurements compare with measurements of pilodyn pin penetration?

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Declaration

I declare that this is the result of my own investigation and that it has not been submitted or accepted in whole or part for any degree, nor is it being submitted for any other degree.

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1. Introduction

The main goal of many tree improvement programmes including the one for Sitka spruce (*Picea sitchensis*) in Great Britain is to increase growth rate while maintaining or enhancing wood quality. The wood quality trait of primary interest is usually wood density. Density is a major determinant of both wood strength and pulp yield, and thus is important for a wide range of forest products

Sitka spruce is a commercially important tree species in the UK and other parts of temperate Europe. Sitka spruce grows relatively rapidly in the UK due to the environmental conditions found here. The trend towards utilisation of younger trees from fast-growing managed stands increases the proportion of lower density juvenile wood being harvested and raises the need for consideration of wood density in selection programmes.

The main objective of the project described here is to compare the density measurements obtained using the pilodyn pin penetration method and the results of measuring tree density using computerised tomography (CT scanning).

The secondary objective is to explain how the CT scanning was carried out and the way in which the complex images were analysed in order to acquire the values for wood density.

2. Literature review

"There are now over 600,000Ha of Sitka spruce (*Picea sitchensis*) in the UK, comprising 28% of the total forested area. There has been much concern that strength properties are likely to be reduced by any practice encouraging faster growth rate and shorter rotation, which is likely to produce a larger cone of lower density juvenile wood (Brazier, 1977; Brazier *et al.*, 1985; Brazier and Mobbs, 1993). Density has been positively correlated with physical wood properties such as bending strength, compression and hardness (Haygreen and Bowyer, 1989)." (Mitchell and Denne 1997)

Traditionally, density has been considered to be the simplest single indicator of wood quality. Wood density is under strong genetic control (Raymond, 1995) and is a trait of interest for incorporation into tree breeding programmes (King *et al.,* 1988). Thus, density has been an important factor when selecting trees in tree breeding programmes. In the UK to date basic density of Sitka spruce in screening for tree breeding programmes has been indirectly assessed by determining the depth of penetration of the pin fired from a pilodyn.

Juvenile wood in conifers differs from mature wood in several ways; for example, it has lower density values, thinner cell walls and shorter trachieds. As the pilodyn operates by penetration of the outer rings it will only assess the density of the outer more mature wood, and hence overestimate the density of the whole tree, especially in older trees (as is the case in this study). In this study the fact that the stand was unthinned will result in trees with narrow outer rings with a high proportion of latewood. This results in low pilodyn pin penetration and too high density estimates.

A pilodyn is a hand-held instrument which fires a flat-nosed pin with a fixed force. The depth of penetration can be read directly from a scale on the top of the instrument, and has shown to be strongly negatively correlated with wood basic density at the point of sampling (Crown 1981, Greaves *et al*., 1996). Pilodyns have been used (extensively) for rapid, non-destructive assessment of density in tree breeding programmes for softwoods (Crown, 1981, King *et al*., 1988).

Although a somewhat unsophisticated method of wood density determination, it is very popular due to the fact that a non-destructive means of assessing traits is advantageous when measuring trees within tree breeding programmes. Although unsophisticated, in some cases a higher level of accuracy is obtained from pilodyn pin penetration than for more advanced non-destructive timber density determination methods. A study by Schimleck *et al.*, (1999) showed that for *Eucaluptus globulus* the error was ± 22 kg m^{-3} when measured using pilodyn pin penetration, whereas when the density of the samples was determined using near-infrared spectroscopy the error was ± 30 kg m^{-3}.

The pilodyn is either fired into the tree at a fixed height or at a height which is recorded at the same time as the reading is taken of penetration depth of the pin. The pilodyn data are then used to select trees for inclusion in breeding programmes or screening of the trees within such a programme. The success of such a technique relies upon the sampling point being representative of the whole tree. Wood density at breast height is strongly correlated with whole-tree wood density (Tackle, 1962, cited by Wang *et al.,* 1999). Although both these studies analysed *Pinus contorta*, there is no evidence to suggest that this is not also the case for *Picea sitchensis*.

Raymond and Macdonald (1997) carried out a study in eucalypts to determine the optimal sampling height for pilodyn measurements. This study found that the optimum sampling point changed with age, and increased as the trees grew taller. This may have been due to the effect of position from the pith. Density is positively correlated with distance from the pith, and the pilodyn only penetrates the outer growth rings of the tree. Thus, increasing the height of the sampling point (given the tapered form of trees) may provide an improved correlation between pilodyn pin penetration and wood density.

It has been shown that in lodgepole pine (*Pinus contorta*) pilodyn pin penetration is strongly and negatively correlated with density at both the individual tree ($r = -0.52$, $P < 0.0001$) and family levels ($r = -0.77$, $P < 0.0001$) (Wang *et al*. 1999). In this study the relationship between pilodyn pin penetration and density is examined in Sitka spruce. In this case, due to the small sample size, the relationship will only be able to be calculated at the individual tree level.

The pilodyn wood tester has been widely used in tree breeding programmes to rank families for wood density. For species with juvenile wood density that declines from pith to the bark, such as Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heteropliylla*), some spruces (*Picea. spp*.) and firs (*Abies spp*.) (Kennedy 1995), valuable fast-growing, high-density families could be wrongly classified as fast- growing but low-density by the pilodyn if no adjustment is made for diameter (Wang *et al*. 1999). This is a potential problem when ranking families or individual trees at an early age.

Density varies considerably across the radial diameter of spruce trees. The general trend is described as a decrease across the juvenile wood from a maximum close to the pith down to a minimum by rings 10 – 20, followed by a slight increase or stabilisation throughout the mature wood to the bark (Mitchell and Denne 1997).

A study of 70-year-old Norway spruce (*Picea abies*) trees in Quebec showed that wood density declines from pith to bark up to the eighth annual ring, stabilizes until the fourteenth annual ring, and increases thereafter (Blouin *et al*. 1994). This suggests that in cases where seed (individual) trees are being selected for wood density as well as for form and growth, some relatively low-density trees could be classed as high-density because the pilodyn method assesses density of only the outer growth rings.

In order to accurately determine the relationship between the density of the cross sectional area of the tree and pilodyn pin penetration at the same height on the stem it is important to acquire the density for the whole cross section. In this study the density was obtained from the images generated by a CT scanner.

CT scanning was used as a method of density determination because it provides a means of determining the density of the whole cross section of the disk. A study by Macedo *et al*., (2002) showed a very high correlation (R^2 = 0.94) between the density as calculated from the data provided by a CT scanner and density values achieved using the gravimetric method.

A CT scanner is a very advanced type of X-ray machine. Instead of sending out a single X-ray beam, as in ordinary machines, several beams are sent out simultaneously from different angles. The X-rays from the beams are detected after they have passed through the entity being scanned and their strength is measured.

Beams that have passed through less dense tissue will be stronger whereas beams that have passed through more dense tissue will be weaker. A computer can use this information to work out the relative density of the tissues examined. The computer processes the results, displaying them as a two-dimensional image on a monitor (Brant, 2005). When viewing these images (as with other X-ray images), the greater the luminosity of the image (or area of the image) the higher the density (i.e. brightness is positively correlated with density)

The technique of CT scanning was developed by the British inventor Sir Godfrey Hounsfield, who was awarded the Nobel Prize for his work.

The CT scanner is normally used within a medical context. Nonetheless, as CT scanners are getting more advanced some of the older models are being removed from hospitals and other medical facilities. These then become available for research in other fields such as agriculture and forestry.

There has been a considerable commitment in order to develop commercial CT scanning equipment for the forest products industry. There are now log scanners scanning (in a commercial environment) using CT scanning techniques. This approach was first suggested by Grundberg, (1999). The studies first carried out showed that an X-ray log scanner with two X-ray sources has great potential as a powerful tool for control of the sawmill process (Oja, 1999). This suggested that such an X-ray scanner could operate at speeds of 3 m/s. This equates to 180 m/minute, which means that such a scanner would be more than capable of keeping pace with the most modern sawing lines.

Oja's (2001) study also showed that such a scanner could be used to measure many important log parameters during scanning. These parameters include the percentage of heartwood and the green heartwood density. From these measures the bending stiffness of the centre boards could be predicted. This would have great benefits as it could lead to production of a high proportion of boards meeting the appropriate stress grading requirements.

If this technique were to be employed on a large scale in Great Britain, a database of these values could be assembled for logs arriving from different forest stands. This information could be used by the Forestry Commission and others to review tree improvement on a larger scale.

Tsehaye *et al.,* (1995) suggested that trees should be bred for wood stiffness and not for wood density, especially if machine grading is to be used commercially. This is due to the fact that machine stress grading is based on the stiffness of the timber. Part of the reason for this suggestion is that the authors were grading *Pinus radiata*. When compared to commercially-important species of the Northern Hemisphere *Pinus radiata* had a very low ranking in terms of stiffness (11/11). The correlation between stiffness and density is lower in *Pinus radiata* than in the commercially-important timber producing species of the Northern hemisphere. In the vast majority of cases wood density is used as a simple indicator of the mechanical properties of timber because there is a high correlation between mechanical properties of wood and its density. Density can also be quantified using non-destructive techniques on standing trees. Nevertheless the point is valid, in that if a database could be created detailing more complex mechanical properties such as stiffness (due to the this being the basis by which mechanical stress grading is carried out) this would lead to further advancements in tree improvement, since selection would be based on the actual mechanical properties of timber, rather than an indicator of such properties.

3. Materials and methods

3.1 Sampling

The project involved taking pilodyn readings in two unthinned Sitka spruce stands, owned and managed by the Forestry Commission. The stands were located at Benmore (Scotland) where wind exposure is low. One of the sample stands (FR3, NM456261) was on a slope and the other (FR4, NM455263) was on level ground. The two stands were planted in 1961. Further site details appear in appendix I.

In order to measure the wind exposure at the sites anemometer masts were erected and were kept in place from July 2002 until September 2003.

After the anemometer masts were removed, pilodyn measurements were taken by staff from Forest Research’s Northern Research Station on a sample of 18 trees in each stand. The 18 sample trees came from three crown/dominance classes, (i.e. six dominant, six codominent and six subdominant trees. Sampling was done by identifying the first six trees in each crown/dominance class that met Forest Research’s straightness criteria (Macdonald et al., 2001). The trees were then felled and an experimental disk was cut from each tree at the point at which the pilodyn measurement had been taken. The height at which the disk was taken was noted.

The disks were then coded as follows: stand number - tree number - height at which the disk was taken (m).

E.g. FR3-98-1.34

The compass orientation was also marked on it.

3.2 CT scanning

The disks were kiln dried to a moisture content of around 12% at Forest Research's Northern Research Station.

The disks were moved to the Scottish Agricultural College buildings adjacent to the Northern Research Station. This is where the CT scanner used in the following was installed.

The moisture content of the disks was measured in both the heartwood and the sapwood, using an electronic moisture meter. The mean of these two results was then calculated. This was done just before the disks were scanned (so there would be as little difference as possible between the moisture content measurements and the moisture content of the disks at the time of scanning).

The disks were then placed on their edge in a semi-circular cradle (so they would not roll off the table), with the western orientation was facing to the right when looking at the disks face on from the front of the scanner. This was done so that when the images were created by the CT scanner they would be of the correct orientation.

Several disks were placed in each cradle, separated by semi-circular hardboard dividers. This was so that a separate image would be created for each disk.

The cradles were placed on the table part of the CT scanner. The table moves linearly through the circular scanning head as images are taken of the sample disks. This was controlled from a room adjacent to the scanner in order to protect the operator (and those assisting the operator) from radiation.

Throughout the scanning data sheets were filled in. This was so that we could be sure that each image corresponded to the correct disk. A spreadsheet displaying the data from the data sheets can be found in appendix II.

The images produced by scanning were saved in the dicom (.DIC) file format. In order to analyse the images they had to be converted from the dicom (.DIC) file format to the bitmap (.BMP) file format. This was done using the program Star 3.2.

Once the images were converted into bitmap form it is possible for the disks to be analysed for timber density and ring width using the computer program Windendro. Windendro calculates the ringwidth in mm and expresses density in terms of pixel values (greyscale). Appendix III describes the Windendro standard operating procedure.

Pixel values (greyscale) represent shades of grey within the following limits:

$$\begin{aligned} 0 &= \text{black (dark)} \\ 255 &= \text{white (light)} \end{aligned}$$

These pixel values are converted to density values using the method described below.

Note: Windendro calculates the density values pixel by pixel along “paths” e.g. on the north path the software would calculate the density within the path progressively from the furthest point due north from the pith, until it reached the pith (Fig.1).

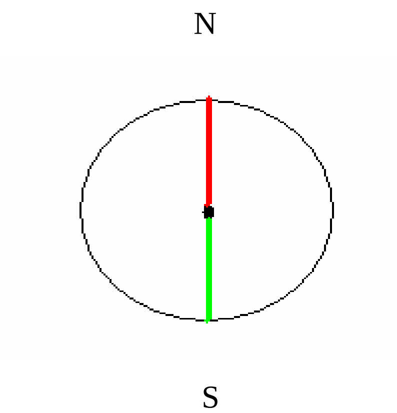


Fig. 1. North and south “paths” (shaded areas), as used by Windendro. Only the density within these shaded areas is calculated.

3.3 Converting the relative grey scale values for density acquired from the images into absolute wood density values.

Step 1: **Convert from grey scale to density (uncalibrated)**

CT images use Hounsfield units. In order to analyse the images the Hounsfield units are converted into bitmap grey scale. In order to acquire the uncalibrated density the greyscale values need to be converted back into Hounsfield units. From these Hounsfield units the uncalibrated density is calculated using the internal calibration used by the CT scanner.

In Star 3.2, Hounsfield values between -812 (-300-512) and 212 (-300+512) are converted into greyscale values from 0 to 255.

$$
\begin{aligned}
-812\,(H) &\equiv 0 \; \textit{greyscale} \\
212\,(H) &\equiv 255 \; \textit{greyscale}
\end{aligned}
$$

The Hounsfield units relate to density as follows:

$$
\begin{aligned}
-1000 \text{ Hounsfield units} &\equiv 0 \text{ kg m}^{-3} \\
0 \text{ Hounsfield units} &\equiv 1000 \text{ kg m}^{-3}
\end{aligned}
$$

Equation 1 combines conversion of greyscale to Hounsfield units with the conversion of Hounsfield units to density.

Equation 1

$$
\textit{Uncalibrated Density}\left(\text{kg m}^{-3}\right) = \left(\frac{\textit{Greyscale value} \times 1.024}{255} + 0.188 \right) \times 1000
$$

Step 2: **Convert from uncalibrated density to calibrated density using regression obtained in the CT scanner using 25 samples of West African hardwoods.**

This is done using equation 2.

Equation 2

$$Calibrated\ Density\ \left(kg\ m^{-3}\right) = \left(\ Uncalibrated\ Density \times 1.04355 + 0.013\ \right) \times 1000$$

Step 3: **adjust calibrated density for measured moisture content in order to calculate the density at 0% MC.**

Equation 3

First calculate (G_M) the specific gravity based on volume at mean moisture content M (%) of the disk analysed.

$$G_M = \frac{Calibrated\ Density}{1 + \left(M \div 100\right)}$$

The density at 0% MC (D_0) is calculated using Equation 4.

Equation 4

$$D_0 = \left(\frac{G_M}{1 + \left(0.009 G_M \times \left(30 - M\right)\right)} \right)$$

$$\textit{Density at 0\% MC} = 1000\ D_0$$

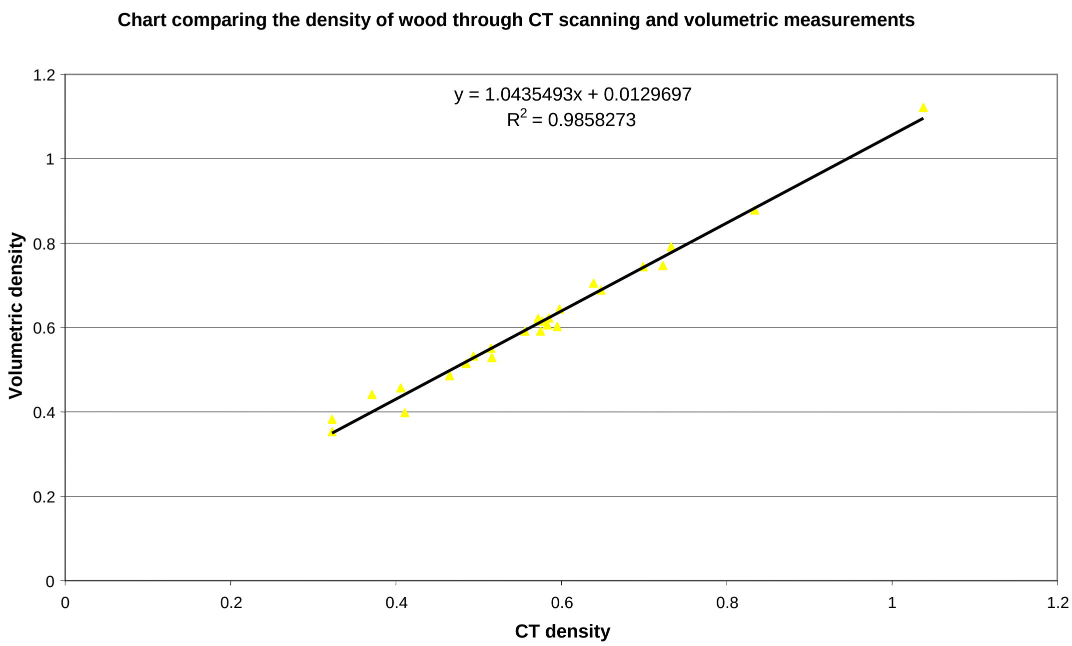
Step 4: **Calculate the density of the sample disk at specific moisture content (MC), e.g. 12%**

Equation 5

$$\textit{Density at specific moisture content}\ \left(kg\ m^{-3}\right) = \left(\frac{D_0\left(1+\left(MC \div 100\right)\right)}{1-0.009D_0 \times \left(30-MC\right)} \right) \times 1000$$

Note : The equations above only apply to moisture contents below 30% (i.e. below fibre saturation point). A study showing further information on equations 3-5 is Simpson, (1993).

This chart shows the relationship between density determined by CT images (calculated using the calibration procedure described in section 3.3), with values obtained by volumetric methods (Gardiner, *pers. comm.*).



(Fig. 2.)

3.4 Analysis

The following analysis of the density data was carried out.

3.4.1 Show the Variation in wood density across the radius of trees at breast height

This was done by plotting all the values for calibrated density (Eq. 2) from pith to bark, for the north and south paths, for two random samples of trees. One sample was taken from the data for FR3 the other from the data for FR4.

3.4.2. Relationship between the mean density values for the north and south paths of the disk (as determined by the CT scanner) and the measurements for pilodyn pin penetration

This was calculated so that the relationship between the density of the disk and pilodyn pin penetration could be measured

This was done by calculating the mean for all the values of calibrated density (Eq. 2) from pith to bark, in the north and south path of all the samples, from both FR3 and FR4. These mean values were then correlated with the pilodyn data which had been already collected for the sample trees.

The figure of 23 pixels was calculated as shown below.

$$\begin{aligned}
\text{Image size} &= 450\text{mm}^2 \\
\text{Image length} &= 512 \text{ pixels} \\
20\text{mm} &\approx \text{distance of pilodyn pin penetration} \\
\\
450\text{mm} &= 512 \text{ pixels} \\
1\text{mm} &= \frac{450}{512} \text{ mm in size} \\
20\text{mm} &= \left(\frac{512}{450}\right) \times 20 \text{ pixels} \approx 23 \text{ pixels}
\end{aligned}$$

4. Results

4.1 Variation in wood density across the radius of trees at breast height

4.1.1 The variation in wood density across the radius (at breast height), for a single random sample tree within stand FR3

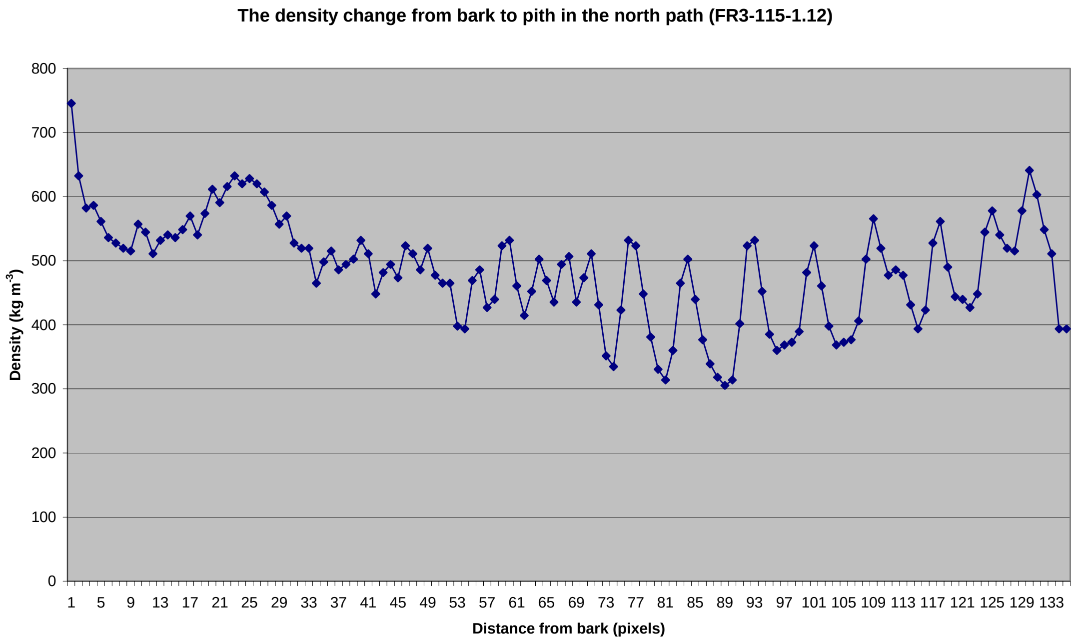


Fig. 3. shows the density change from bark to pith (kg m^{-3}), in the north path of tree FR3-115-1.12

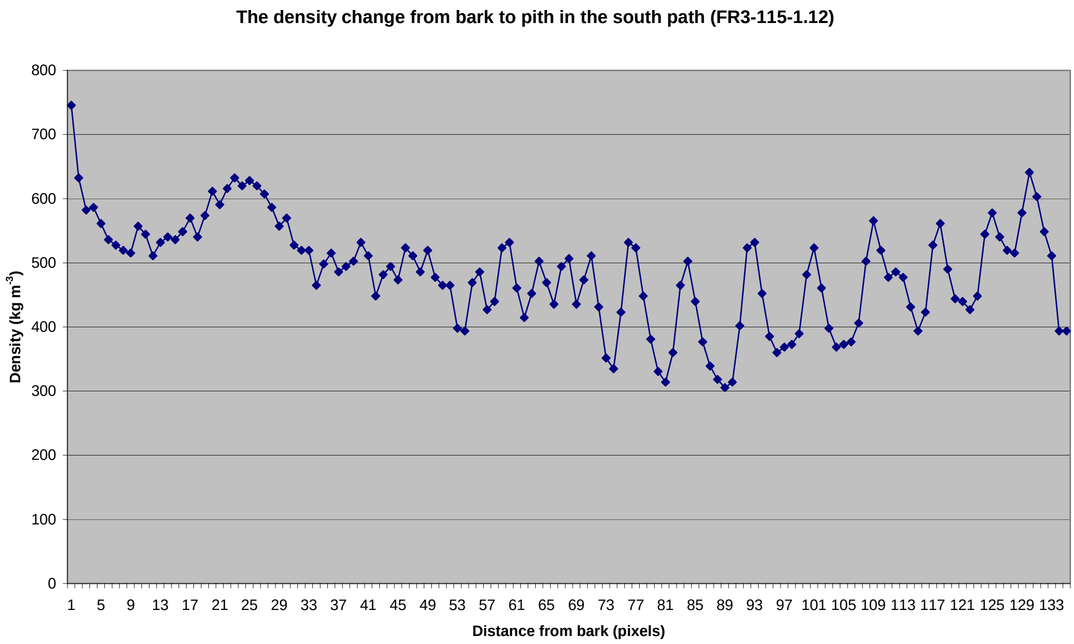


Fig. 4 . shows the density change from bark to pith (kg m^{-3}), in the south path of the same tree.

<u>4.1.2 The variation in wood density across the radius (at breast height) for a single random sample tree within stand FR4. (FR4-500-1.48)</u>

Fig. 5 . shows the density change from bark to pith (kg m^{-3}), in the north path and Fig. 6. shows the density change from bark to pith (kg m^{-3}), in the south path of tree FR4-500-1.48

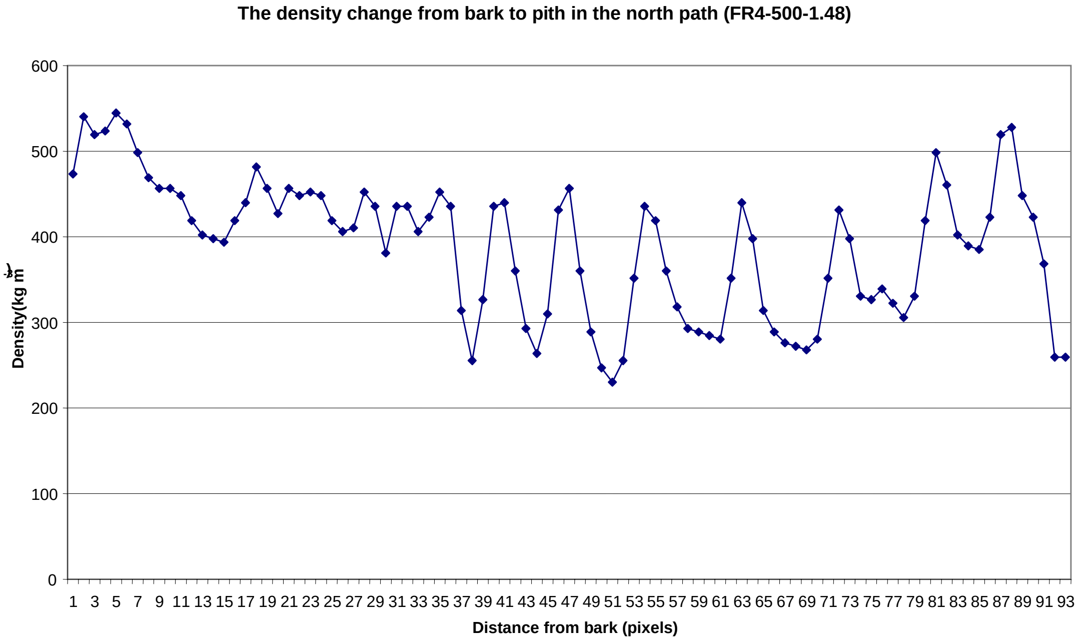

The density change from bark to pith in the north path (FR4-500-1.48)
Density(kg m⁻³)
Distance from bark (pixels)
600
500
400
300
200
100
0

Fig. 5.

.

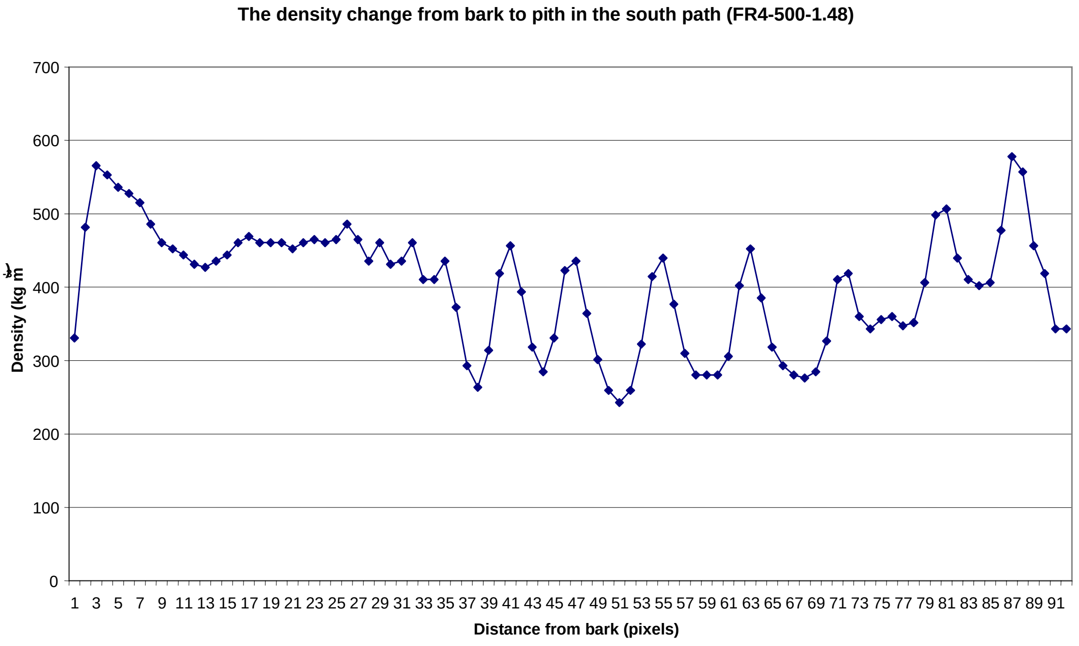

The density change from bark to pith in the south path (FR4-500-1.48)
Density (kg m⁻³)
Distance from bark (pixels)
700
600
500
400
300
200
100
0

Fig. 6.

4.2 Relationship between the mean density values for the north and south paths of the disk (as determined by the CT scanner) and the measurements for pilodyn pin penetration

Fig. 7. shows the in stand FR3 and Fig. 8. the relationship in FR4.

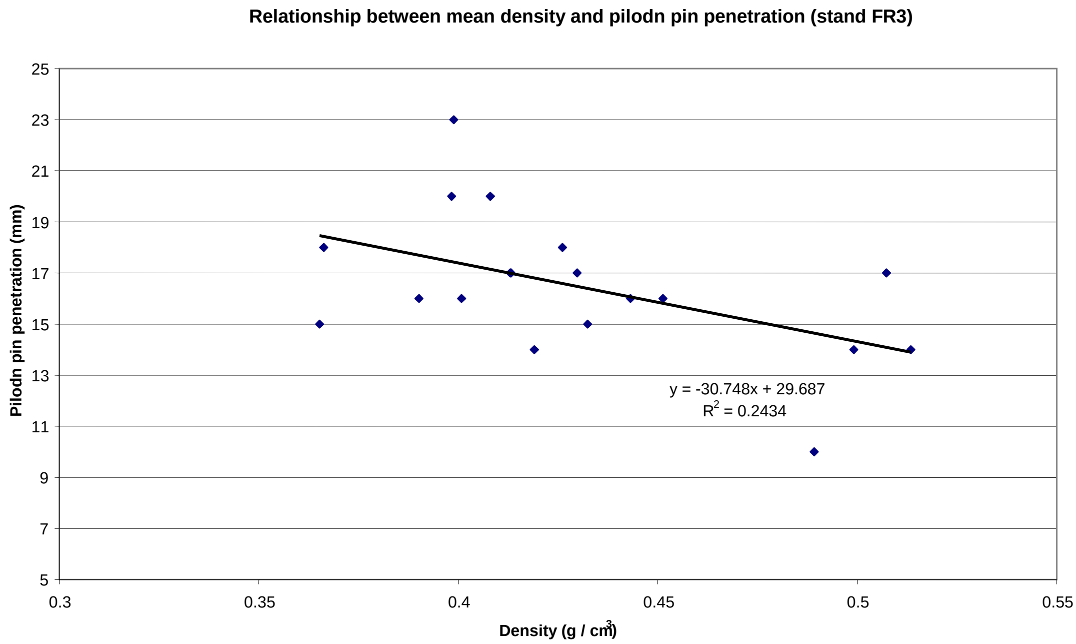


Fig. 7.

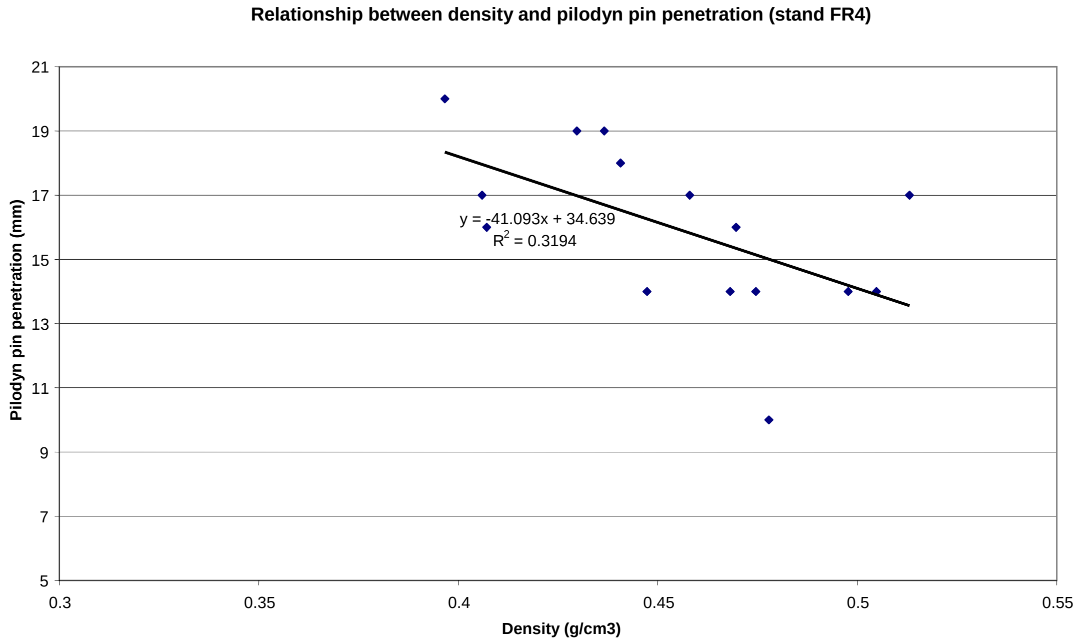


Fig. 8.

4.3 Relationship between the mean density values for the outer 20 mm of the disk and the measurements for pilodyn pin penetration

Fig. 9. shows the relationship in stand FR3 and Fig. 10 the relationship in stand FR4.

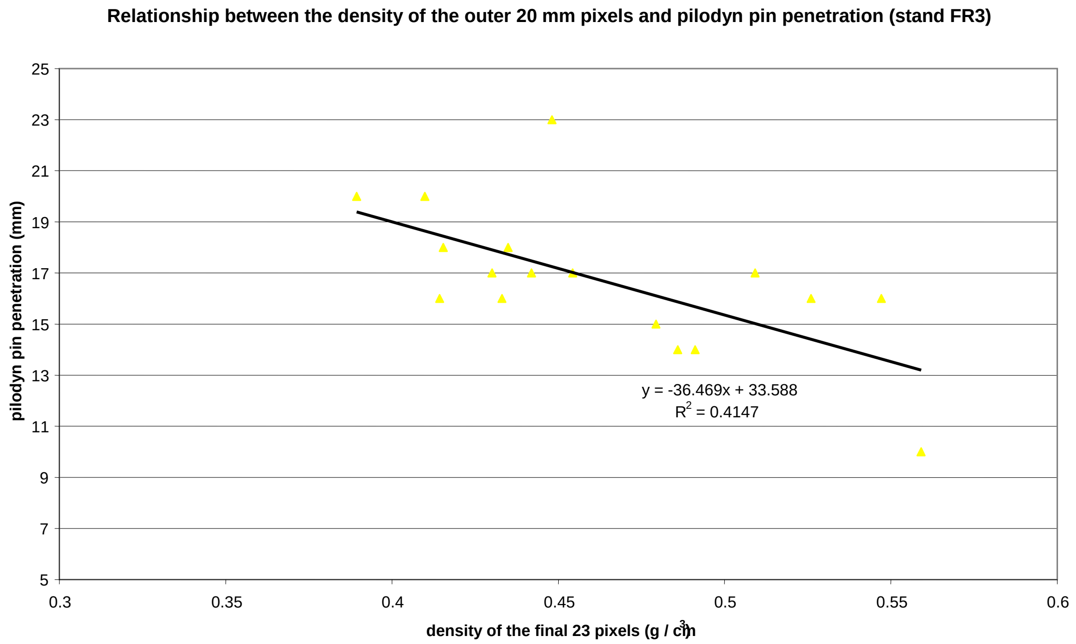


Fig. 9

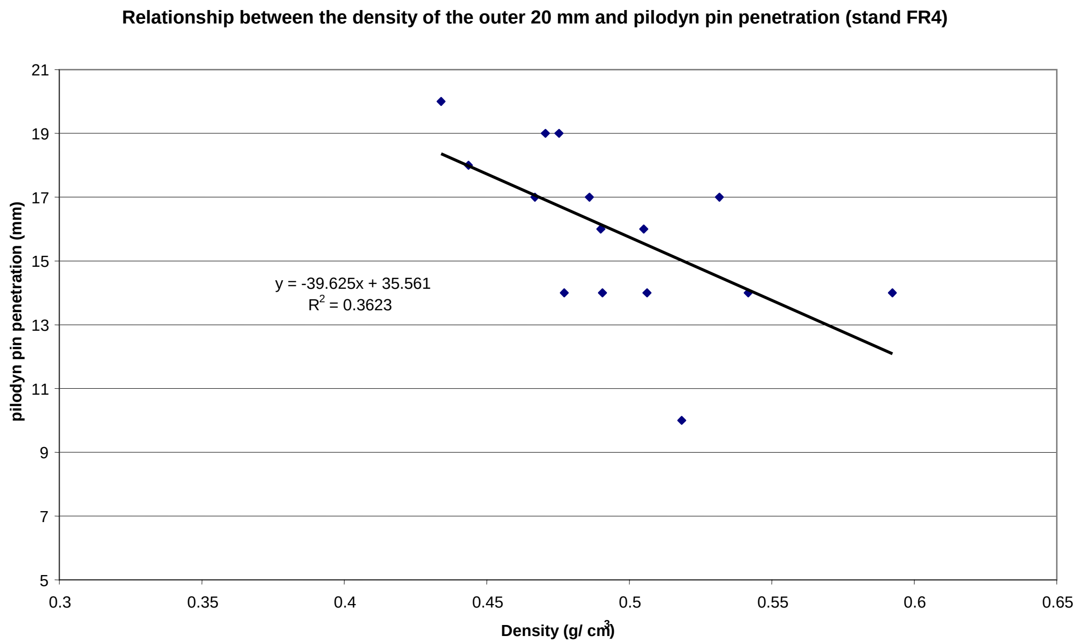


Fig. 10.

5. Discussion

5.1 CT Scanning

The density determined from CT images and calibrated using the method outlined shows a very strong correlation with the density of the same samples measured using the volumetric method. This is consistant with a very strong correlation found by Macedo *et al.* (2002).

This shows that CT scanning is a highly accurate as a means of determining wood density. However, care needs to be taken because although the CT scanner is very accurate in determining specific gravity (i.e. the relative densities within the material being scanned), this accuracy can only be maintained when calculating the absolute density of wood when the correct calibration is used.

As shown in section 4.1 the method proposed is not limited to measuring the average density of a disk but can also determine the density distribution across a sample radius. Thus, the heterogeneity of wood density can be quantitatively determined.

5.2 Relationship between density and pilodyn pin penetration

There are many factors affecting the relationship between the mean density values for a path (e.g. north and south paths) of a disk and pilodyn pin penetration at the same height in the tree. One factor is that the pilodyn only penetrates the outer growth rings of the trees. Therefore, due to the fact that for Sitka spruce timber density is not relatively constant across a radius an analysis of the relationship would probably show a poor correlation (as was the case in this study).

One of the difficulties when using the Windendro program was that it analysed density along paths rather than the density of the whole disk. It would be possible (but not done in this study) to weight the density values for the path by their distance from the pith and then estimate the density of the disk. Due to the circular shape of the disk the values for density closer to the pith would represent a smaller proportion of the total area than those further away. This measurement of density along paths also lead to problems where defects in the wood are intersected by the paths; this can lead to a false representation of density. On two occasions in this study data had to be disregarded in cases where the paths crossed large cracks which had developed in the disks during drying.

Windendro allows the analysis of up to 32 paths. Use of all these paths would give a very high degree of accuracy in terms of density measurement. A statistical analysis could be carried out in order to calculate the number of paths required to acquire an acceptably accurate value for the density of the disk.

In an attempt to improve this relationship between density and pilodyn pin penetration the mean density of the outer 23 pixels was considered. This is the density of the timber which the pilodyn actually penetrates and could therefore be regarded as a true relationship between timber density and pilodyn pin penetration. The coefficient of determination (R^2) was found to be only moderate. The literature suggests that because the pilodyn only penetrates the outer rings of the tree (the relatively dense mature wood), pilodyn measurements lead to overestimates in wood density. This was the case for stand FR3. However, for stand (FR4) the data was less clear cut, with the pilodyn overestimating and underestimating density in similar numbers of trees.

6. Conclusions

The method proposed for determining wood density using a CT scanner is significantly accurate.

In the Sitka spruce (*Picea sitchensis*) samples; there is at best only a moderate correlation between pilodyn pin penetration and wood density.

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Appendix 1

(Data gathered by Forest Research, contains background information and data for site FR3 and FR4.)

Sitka spruce (Stands FR1 – FR4, Lochaline and Benmore)

Four unthinned, pure Sitka spruce stands, owned and managed by the Forestry Commission, with variations in site slope and wind exposure were studied. These comprised a level stand and a steep stand at Lochaline on the west coast of Scotland, where wind exposure is high, and a level stand and a steep stand at Benmore, which is inland, where wind exposure is low (Figures 2.1 – 2.3). Anemometer masts were erected at Lochaline and Benmore to compare the wind climates over a twelve month period. The key site and stand characteristics are summarised in Table 2.2, and the diameter distribution is shown in Figure 2.4.

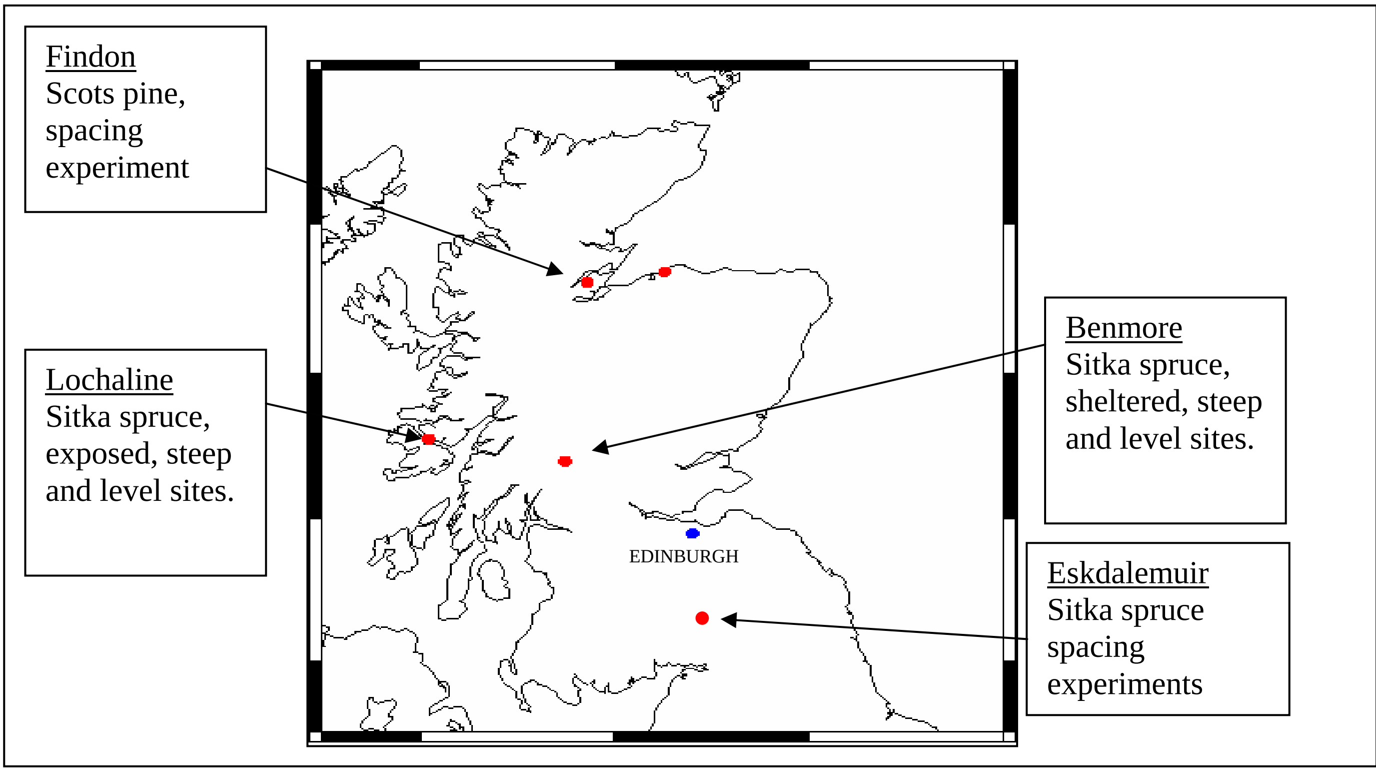


Figure 2.1: Location of Sample Stands in Great Britain

Figure 2.2: Level and steep Sitka spruce stands (FR1 & FR2) in exposed location at Lochaline

Figure 2.3: Level and steep Sitka spruce stands (FR4 & FR3) in sheltered location at Benmore

Table 2.2 Site and Stand Characteristics for Sitka spruce stands (FR1 – FR4)

	Lochaline		Benmore	
	FR1	FR2	FR3	FR4
Number of live trees per hectare	1360	1476	1443	1712.5
Top Height (m)	26.6	26.9	28.1	24.5
Planting Year	1954	1954	1961	1961
Age at felling	48	48	42	42
General Yield Class	18	18	24	18
Mean dbh (cm)	28.4	26.1 cm	24.6	22.3
Mean tree volume (m^3)	0.69	0.59	0.53	0.38
Average Slope (Degrees)	3	24	23	6
Mean Hourly Wind Speed (m/s)	7.0		3.3	

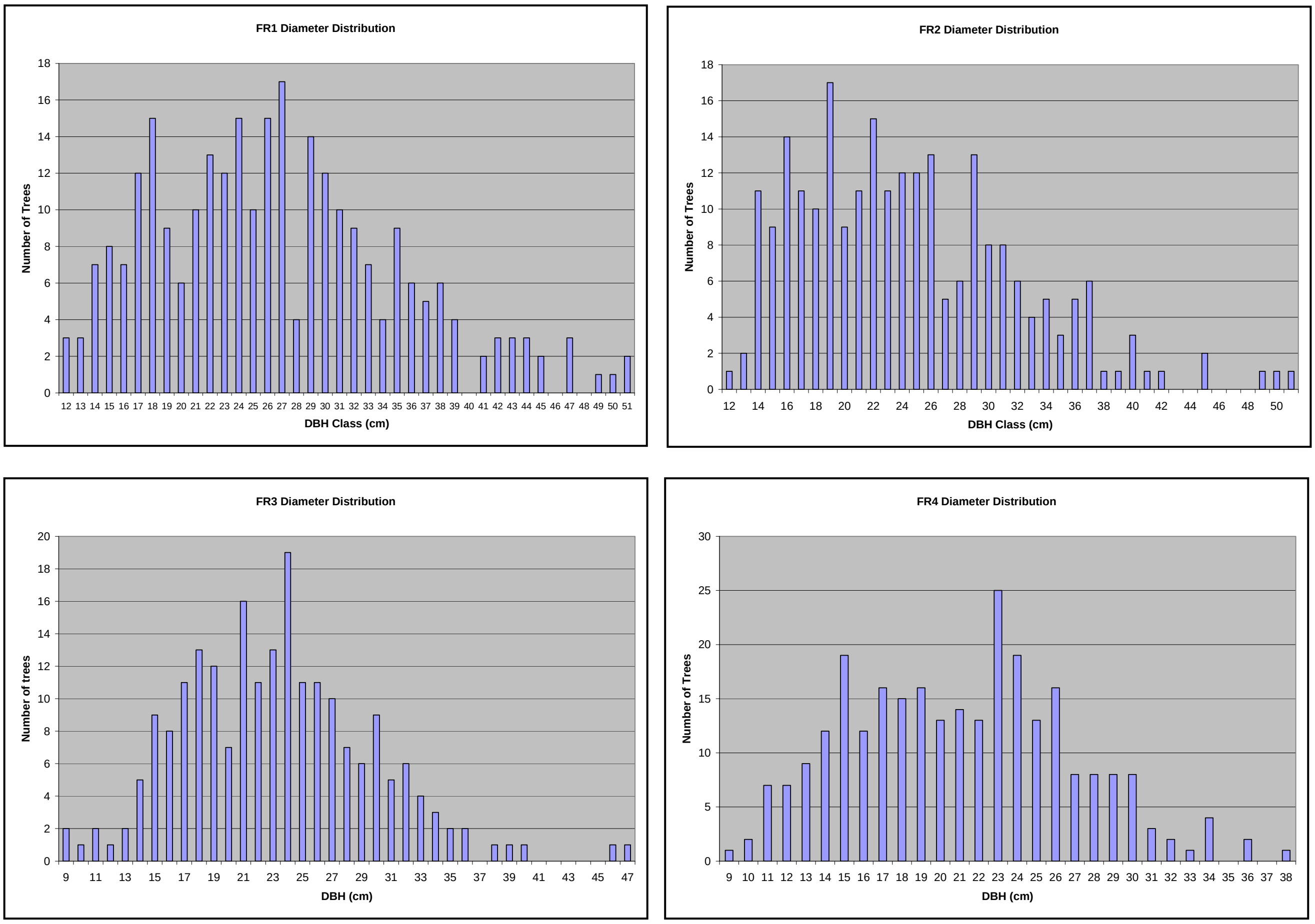


Figure 2.4: Diameter distribution in Sitka spruce stands FR1-FR4

The stem form class of trees in each stand was measured based on the lean of the stem in the lowest 4m according to the protocol set out in Annex 1. The classes were determined as follows:

- Stem Form Class 1: Maximum deviation from the vertical in the first 4m of the stem is <1%
- Stem Form Class 2: Maximum deviation from the vertical in the first 4m of the stem is from 1% to 2% inclusive
- Stem Form Class 3: Maximum deviation from the vertical in the first 4m of the stem is >2%

The stem form class distribution for the Sitka spruce stands at Lochaline and Benmore are shown in Figure 2.5. In both the Lochaline stands about 60% of the trees fell within the straightest stem form class (Stem Form Class 1). In both the stands at Benmore, however, the distribution of Stem Form Classes was reversed, with more than 50% of trees falling within the poorest stem form (Stem Form Class 3). Factors other than wind loading appear to have had an overriding effect on stem form. It seems likely that either genetic origin or differences in soil type and stability (or a combination of both) have resulted in the poorer form of the trees at Benmore. The Benmore soils were generally very wet with restricted rooting depth, resulting in poor stability throughout the life of the stand.

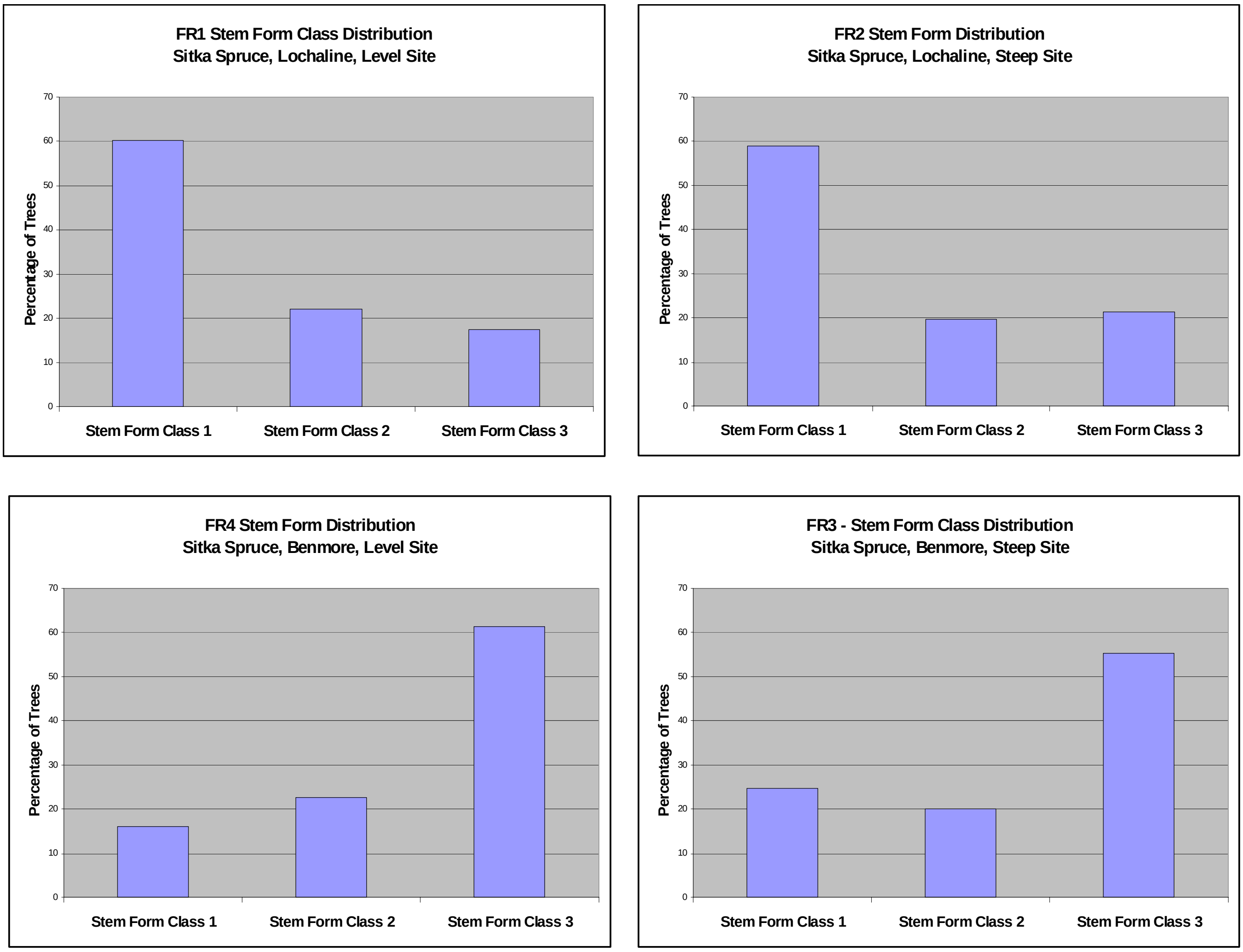


Figure 2.5: Stem form class distribution for stands FR1-FR4

Monitoring of the wind climate at Lochaline (FR1 & FR2) and Benmore (FR3 & FR4) continued from July 2002 until September 2003. The data collected support the assessment that wind speeds in the more exposed stands at Lochaline were higher than those at the sheltered Benmore site, as shown in Figure 2.6 below.

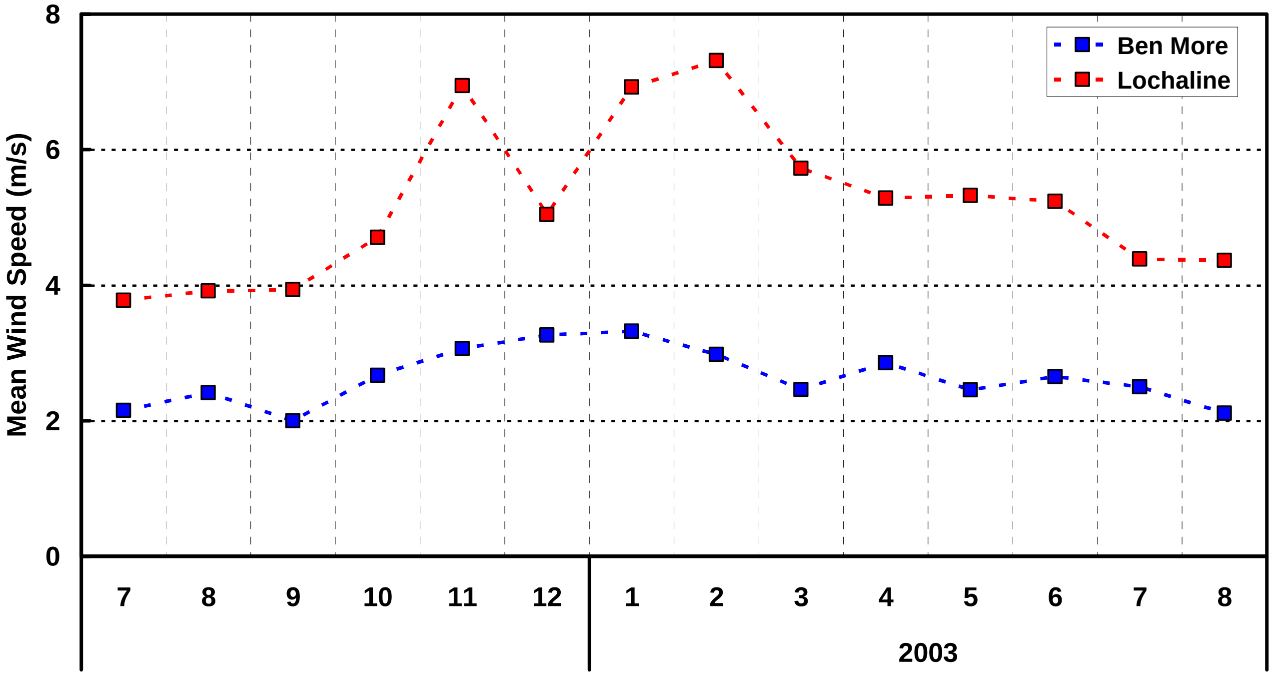


Figure 2.6: Wind monitoring data for Lochaline and Benmore (Sites FR1/FR2 and FR3/FR4))

Detailed tree characterisation was completed on a sub-sample of trees in each stand, in accordance with the agreed protocol, i.e. 18 scientific and 16 industrial sample trees from each stand. This included measuring diameter at breast height, direction of maximum lean, local slope of the ground, maximum angle of lean in the first 4m, competition index, crown shape and wood density at breast height (using the Pilodyn pin penetration method).

The outer shape of each sample tree was assessed, in the direction of maximum deviation and at right angles to this, using an Impulse Laser rangefinder, as described in Annex 1. Stem shape can be plotted from the measurements made, and later compared with the compression wood incidence in individual discs and the three-dimensional log scans made in industrial evaluation. Orthogonal photographs of each sample tree were also taken, showing the profile of the lower part of the stem of the tree that was being assessed. Figure 2.7 shows examples of the type of profile plotted from the laser data.

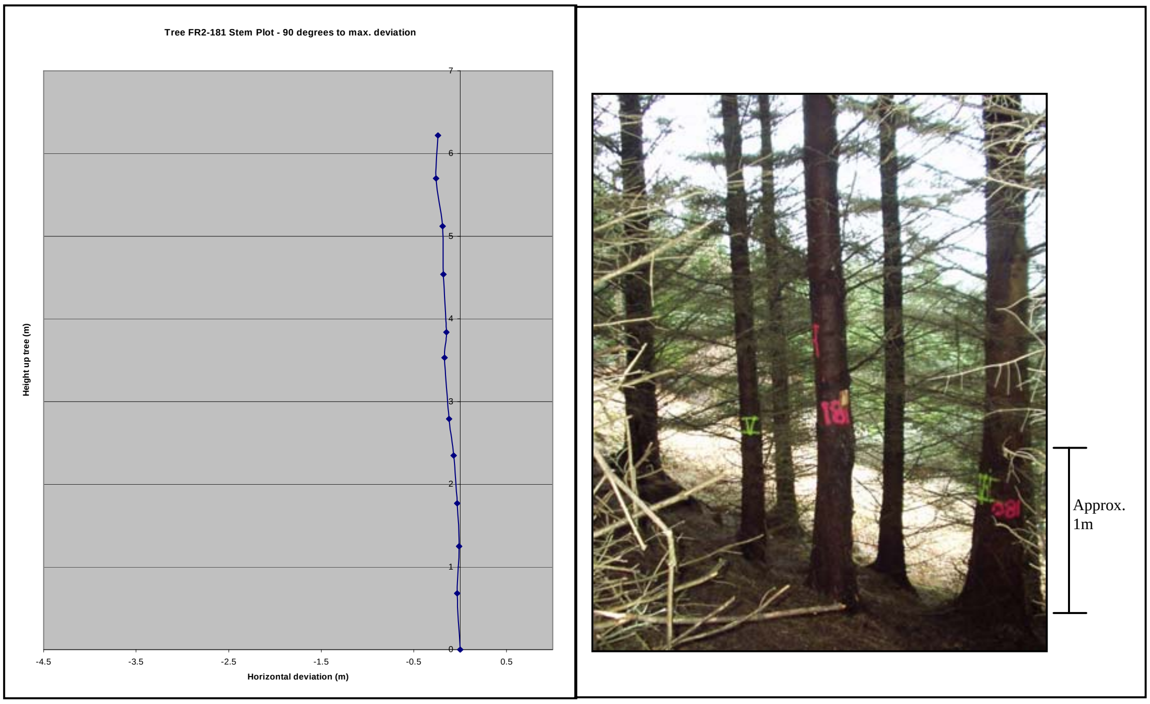


Figure 2.7: Stem shape profile plotted from laser data and photograph showing the actual profile of the same tree

Industrial trees were cut into three 3-metre logs plus four discs, in accordance with the protocol. Discs were cut from the scientific trees approximately each metre up the stem with extra discs being cut from parts of the tree with bends. The butt ends of the logs were marked to show compass direction, so that the position of each batten in the stem, in relation to slope and wind direction, could be described following industrial processing (Figure 2.8). Sawlogs from all the Sitka spruce stands were transported to Adam Wilson and Sons sawmill in Troon, for processing and industrial evaluation. All sample discs were taken to Northern Research Station for analysis of compression wood content, disc eccentricity wood density, grain angle and growth.

Figure 2.8: Marking of log end to show location of battens

Appendix II

Spreadsheet displaying the data from the data sheets - taken during the CT scans

Cradle No.	Position in Cradle	Stand Ref.	Tree No.	Length from base to disc	MC Sap-wood	MC Heart-wood	Time of Scan	Table Position
1	1	FR3	192	1.44	12.0	11.6	17:34:28	-807
1	2	FR3	98	1.34	11.6	11.3	17:34:36	-991
1	3	FR1	6	1.39	11.5	11.1	17:34:43	-1073
1	4	FR3	203	1.42	12.0	11.5	17:34:51	-1151
1	5	FR1	123	1.26	13.6	12.5	17:34:58	-1245
1	6	FR1	202	1.24	12.2	12.2	17:35:06	-39
1	7	FR1	169	1.43	13.8	13.3	17:35:13	-261
1	8	FR1	74	1.62	14.0	13.5	17:35:32	-479
1	9	FR3	168	1.27	11.3	11.1	17:35:39	-531
2	1	FR1	208	1.30	14.2	13.3	17:45:24	-683
2	2	FR4	521	1.26	12.3	12.7	17:45:31	-43
2	3	FR3	81	1.27	12.3	12.6	17:45:39	-621
2	4	FR1	38	1.27	11.8	11.2	17:45:46	-649
2	5	FR4	439	1.17	12.0	12.9	17:45:54	-727
2	6	FR4	376	1.24	12.0	11.6	17:46:01	-909
2	7	FR1	90	1.42	12.7	11.8	17:46:09	-1333
2	8	FR1	255	1.31	12.3	12.6	17:46:26	-181
2	9	FR3	65	1.13	12.5	13.0	17:46:33	-595
2	10	FR1	157	1.20	12.4	12.1	17:46:40	-119
3	1	FR1	249	1.37	11.9	11.7	17:54:49	-331
3	2	FR3	137	1.19	11.8	12.0	17:54:49	-403
3	3	FR4	553	1.34	11.4	11.8	17:55:04	-471
3	4	FR4	338	1.24	11.9	11.8	17:55:11	-551

Appendix III.

WINDENDRO

Standard Operating Procedure

Key words: Pixel values, Ring width, Computer analysis, Windendro.

Category: Assessment.

Title: Measurement of pixel values and ring widths using Windendro software.

Scope: This procedure is for determining the pixel values and ring widths of tree disk images obtained using CT scanning techniques and analysed using Windendro software.

Method:

1. Convert the image file from the original file format into bitmap file format (.bmp). This is done using Star 3.2.

2. Open the image that needs to be analysed in paint Shop Pro.

3. Colour the area around the disk white.

The simplest way to do this is to create a white circle outline larger than the disk. Then fill the outer area with the colour white.

(An example is shown on the next page.)

Using the dropper tool ensure that the black area surrounding the disk is equal to 0 and that the white area around the edge of the image is equal to 255.

This is done so the Windendro software has a reference point to work from.

i.e. Windendro will assign the darkest part of the image the pixel value 0 and the lightest part of the image the pixel value 255. Therefore, there must be pixels of those values.

4. Save the new image using the following notation:
   (Site ID-Tree ID-Disk IDw)
   (ex.: FR4-500-1.39w)

Disk ID is the height at which the disk was taken from the tree.

w - notes that white has been added to the image.

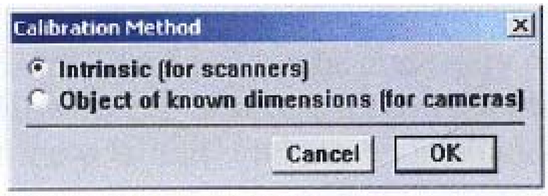
5. Save the image file to a folder of the same name.

6. Install the Windendro key into the Parallel port.

7. Open Windendro software (a select source box will then open).

8. Press the “Cancel button” on the select source box (as the sample was scanned beforehand using the CT scanner).

9. From the top menu of the main view of Windendro, select, Calibration>Method>Intrinsic and select “Intrinsic (for scanners)”. Then press OK (the Intrinsic method is the one to be used for scanned images).



10. A resoulution box will then open asking for the resolution of the image (d.p.i.).

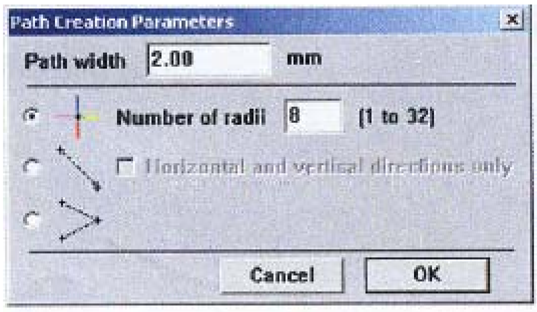
This is calculated as follows:

Image size = 450 mm^2
Number of pixels = 512

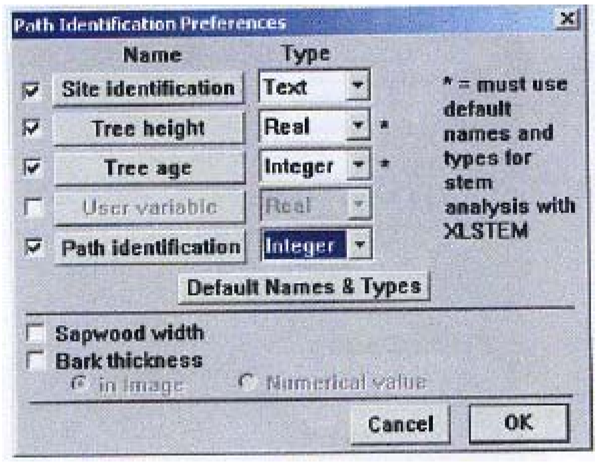
$$450\text{mm} \div 25.4 = 17.72\text{inches}$$

$$\frac{\text{pixels}}{\text{inches}} = \frac{512}{17.72} = 28.9\text{d.p.i}$$

11. From the top menu of the main view of Windendro, select, Path>Creation Parameters and enter the path width and the number of radii that are needed for the analysis. By default, Windendro uses a path width of 2.00mm. then press OK.



12. From the top menu of the main view of Windendro, select, Path>Identification Preferences, then tick the “path identification” option and select “text” (this allows the user to name each path one by one). Then press OK.



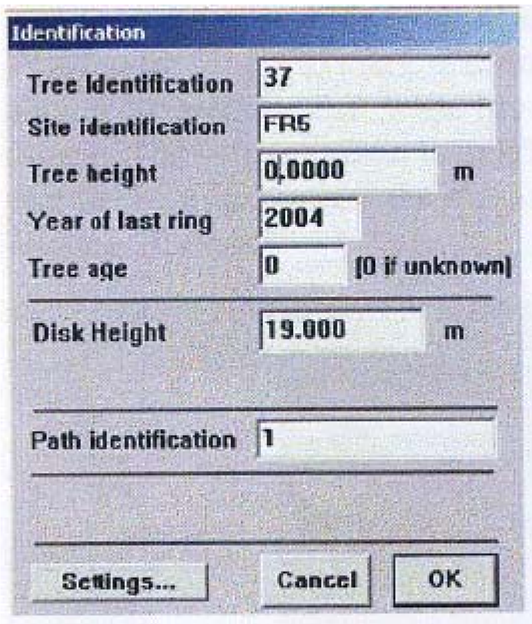
13. From the top menu of the main view of Windendro, select Data>Ring Based Data Files Format and select the option "From Bark to Pith" in the Order section. Then Press OK'

Steps 1 to 12 need to be done only once at the beginning of the project'. However, it is necessary to verify the options ticked from steps 8 to 12 every time you start working with Windendro.

14. Press on the floppy disc icon to acquire the image to be analysed.

15. With the red cross cursor, click the pith centre of the opened image (an identification box will then open).

16. Fill in the Identification box and write "South” at the Path identification ‘Then press OK’ (This is due to Windendro naming the south path first).



17. Another box will then open asking where to save the data. If it is the first time you are analysing a disc from the tree being analysed, press the "Create one" button. Alternatively, press the "Open one" button and open the file where you previously saved the information.

Create a folder named by the site ID, tree ID and the height at which the disk was taken.

This is due to the fact that Windendro automatically saves the results to the folder in which the new data file is situated. Therefore, giving the folder the same name will help to avoid confusion.

18. Fill in the path radii name box. “South” will appear highlighted as it was input into the ‘path identification’ box. Delete the word south and type in north (if using 2 paths) as the program has already named the south path. Then press OK.

Note: Windendro names the paths in the following order:

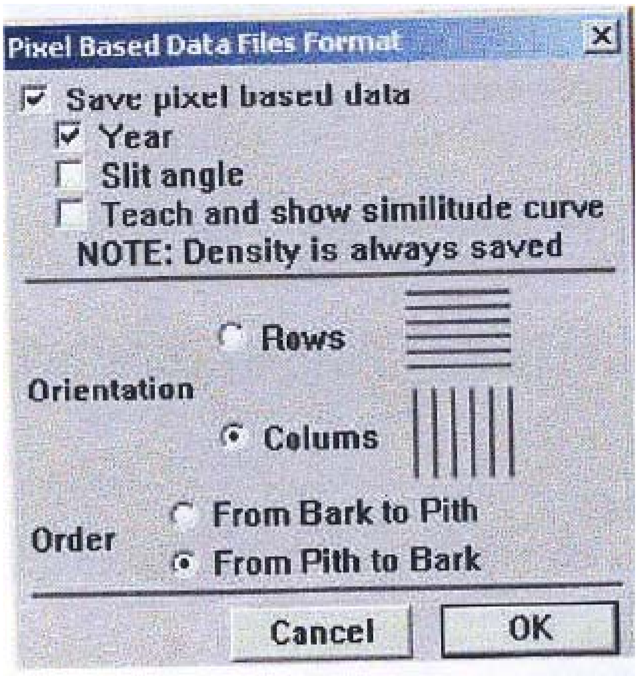
South, North, East, West

19. The ring detection have now been performed by Windendro. To ensure that Windendro recognised all rings properly, look at each ring one by one.

if Windendro did not recognise the ring properly), select it with the red cross cursor (the mark will pass from green to yellow) and delete it with the
left hand button of the mouse. The ring will then be deleted. Conversely if Windendro forgot to mark one ring, position the red cross cursor over the annual growth ring that wasn't recognised and click on the left button of the mouse. The ring will then be marked. Try to ensure that all paths have the same number of rings (In an image with low resolution and a high density of growth rings this can be difficult).

[The data for ring width has now been saved in the folder created in part 17. it is now time to set up windendro to calculate the pixel values for the image]

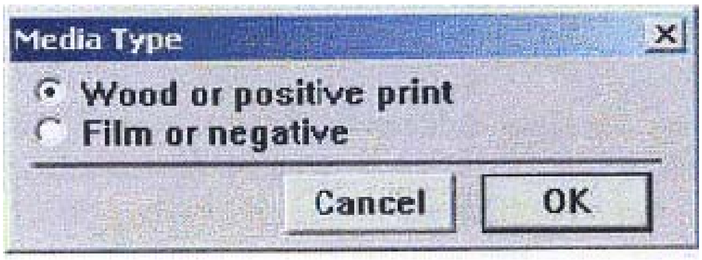
20. From the main menu of the main view of Windendro select Data>Pixel Based Data and tick the "save pixel based data" option' Select the option "Columns" in the Orientation section and the option "From Pith to Bark" in the Order section too. Then press OK.



A dialog box will now appear. It tells the user that the new data will not be saved unless the paths are reactivated. Therefore double click on all the paths to reactive them and this will mean that the data for density will be saved.

21. From the top menu of the main view of Windendro, select Density>Light Calibration Parameters and tick "None". Then press OK.

22. From the top menu of the main view of Windendro, select Density>Media Type and choose the "Wood or positive print" option. Then press OK.



23. From the top menu of the main view of Windendro, select Data>Close File. This will end the analysis.

24. Close Windendro and open the folder (data file) created in part 17. Save the original image created in part 4 to this file also (so the data set is complete).

When the analysis is complete each folder will contain four files:

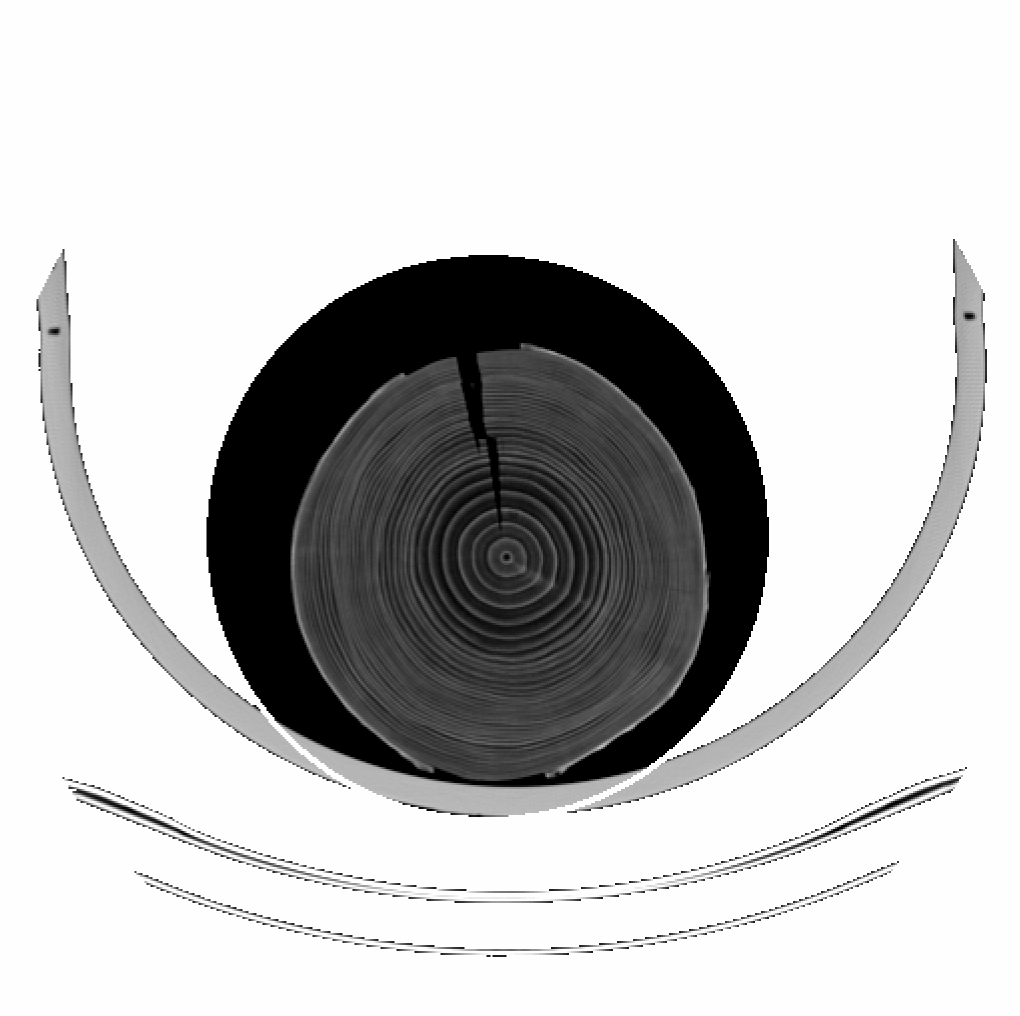
The image (ex.: FR4-500-1.39w.bmp).
The pixel values (ex.: FR4-500-1.39w.pxb)
The ring width values (ex.: FR4-50-1.39w.txt
The path file (ex.: FR4-500-1.39w.pat)

[N.B. if when opening the pixel value files (.pxb) the computer asks you to select a program to open the file, choose Microsoft excel]

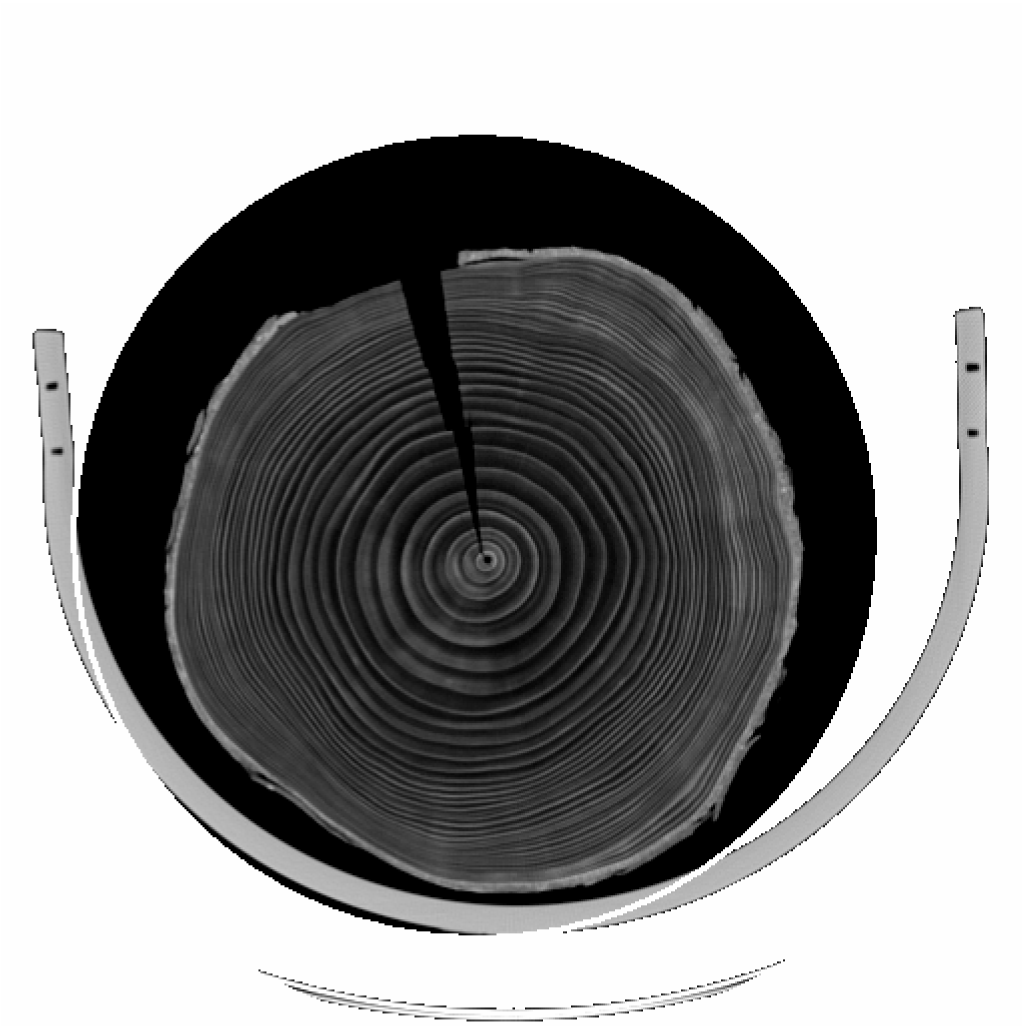
Appendix IV

Two Sample images and the corresponding data sets.

FR3-86-1.35



FR4- 521-1.26



SOUTHERN PATH

WINDENDRO		3	Uncalibrated	Calibrated		Moisture	Density at	Density at
SAMPLE		86	Density	Density		Content %	0% MC	12 MC
THICKNESS mm		1						
SLITLENGTH mm		2						
SLITWIDTH mm		0.878893						
HPIXELSIZE mm		0.878893						
VPIXELSIZE mm		0.878893						
DATA								
DENSITY		YEAR						
	132	1						
	61	1						
	10	1						
	9	1						
	29	2002	0.3044549	0.330714	0.29794	11	0.283497	0.332384
	57	0	0.41689412	0.44805	0.403649	11	0.377586	0.449971
	69	2001	0.46508235	0.498337	0.448952	11	0.416943	0.500311
	65	0	0.44901961	0.481574	0.433851	11	0.403887	0.483535
	59	2000	0.42492549	0.456431	0.411199	11	0.384185	0.458364
	59	1	0.42492549	0.456431	0.411199	11	0.384185	0.458364
	61	0	0.43295686	0.464812	0.41875	11	0.390768	0.466755
	61	1999	0.43295686	0.464812	0.41875	11	0.390768	0.466755
	62	1	0.43697255	0.469003	0.422525	11	0.394054	0.47095
	67	1998	0.45705098	0.489956	0.441401	11	0.410423	0.491923
	68	1	0.46106667	0.494146	0.445177	11	0.413685	0.496117
	65	1997	0.44901961	0.481574	0.433851	11	0.403887	0.483535
	62	0	0.43697255	0.469003	0.422525	11	0.394054	0.47095
	60	1996	0.42894118	0.460622	0.414974	11	0.387479	0.462559
	58	0	0.4209098	0.45224	0.407424	11	0.380888	0.454168
	57	0	0.41689412	0.44805	0.403649	11	0.377586	0.449971
	53	1995	0.40083137	0.431288	0.388547	11	0.36434	0.433184
	59	0	0.42492549	0.456431	0.411199	11	0.384185	0.458364
	76	1994	0.49319216	0.527671	0.475379	11	0.439641	0.529661
	73	1	0.4811451	0.515099	0.464053	11	0.429936	0.517084
	70	1993	0.46909804	0.502527	0.452727	11	0.420197	0.504505
	71	0	0.47311373	0.506718	0.456503	11	0.423447	0.508698
	67	1992	0.45705098	0.489956	0.441401	11	0.410423	0.491923
	66	0	0.45303529	0.485765	0.437626	11	0.407157	0.487729
	66	0	0.45303529	0.485765	0.437626	11	0.407157	0.487729
	64	1991	0.44500392	0.477384	0.430076	11	0.400613	0.47934
	64	1	0.44500392	0.477384	0.430076	11	0.400613	0.47934
	63	1990	0.44098824	0.473193	0.4263	11	0.397336	0.475145
	64	1	0.44500392	0.477384	0.430076	11	0.400613	0.47934
	72	1989	0.47712941	0.510908	0.460278	11	0.426694	0.512891
	72	0	0.47712941	0.510908	0.460278	11	0.426694	0.512891
	70	1988	0.46909804	0.502527	0.452727	11	0.420197	0.504505
	68	0	0.46106667	0.494146	0.445177	11	0.413685	0.496117
	64	0	0.44500392	0.477384	0.430076	11	0.400613	0.47934
	65	1987	0.44901961	0.481574	0.433851	11	0.403887	0.483535
	68	0	0.46106667	0.494146	0.445177	11	0.413685	0.496117
	68	1986	0.46106667	0.494146	0.445177	11	0.413685	0.496117
	65	1985	0.44901961	0.481574	0.433851	11	0.403887	0.483535
	64	1	0.44500392	0.477384	0.430076	11	0.400613	0.47934
	66	0	0.45303529	0.485765	0.437626	11	0.407157	0.487729

66	1984	0.45303529	0.485765	0.437626	11	0.407157	0.487729
66	1	0.45303529	0.485765	0.437626	11	0.407157	0.487729
59	1983	0.42492549	0.456431	0.411199	11	0.384185	0.458364
53	1	0.40083137	0.431288	0.388547	11	0.36434	0.433184
56	0	0.41287843	0.443859	0.399873	11	0.374281	0.445775
52	1982	0.39681569	0.427097	0.384772	11	0.361018	0.428987
53	1	0.40083137	0.431288	0.388547	11	0.36434	0.433184
55	0	0.40886275	0.439669	0.396098	11	0.370971	0.441578
49	1981	0.38476863	0.414525	0.373446	11	0.35103	0.416393
50	1	0.38878431	0.418716	0.377222	11	0.354363	0.420591
56	0	0.41287843	0.443859	0.399873	11	0.374281	0.445775
55	0	0.40886275	0.439669	0.396098	11	0.370971	0.441578
52	0	0.39681569	0.427097	0.384772	11	0.361018	0.428987
55	1980	0.40886275	0.439669	0.396098	11	0.370971	0.441578
58	0	0.4209098	0.45224	0.407424	11	0.380888	0.454168
58	0	0.4209098	0.45224	0.407424	11	0.380888	0.454168
61	1979	0.43295686	0.464812	0.41875	11	0.390768	0.466755
61	1	0.43295686	0.464812	0.41875	11	0.390768	0.466755
52	1	0.39681569	0.427097	0.384772	11	0.361018	0.428987
50	1978	0.38878431	0.418716	0.377222	11	0.354363	0.420591
62	0	0.43697255	0.469003	0.422525	11	0.394054	0.47095
62	0	0.43697255	0.469003	0.422525	11	0.394054	0.47095
46	0	0.37272157	0.401954	0.36212	11	0.341004	0.403798
36	1977	0.33256471	0.360048	0.324367	11	0.307321	0.361798
43	1	0.36067451	0.389382	0.350794	11	0.330943	0.3912
52	0	0.39681569	0.427097	0.384772	11	0.361018	0.428987
45	0	0.36870588	0.397763	0.358345	11	0.337655	0.399599
35	0	0.32854902	0.355857	0.320592	11	0.30393	0.357597
31	0	0.31248627	0.339095	0.305491	11	0.290325	0.340789
29	1976	0.3044549	0.330714	0.29794	11	0.283497	0.332384
38	1	0.34059608	0.368429	0.331918	11	0.314091	0.3702
52	0	0.39681569	0.427097	0.384772	11	0.361018	0.428987
48	0	0.38075294	0.410335	0.369671	11	0.347692	0.412195
32	0	0.31650196	0.343286	0.309266	11	0.293732	0.344992
23	0	0.28036078	0.30557	0.275289	11	0.262912	0.307164
20	0	0.26831373	0.292999	0.263963	11	0.252563	0.294551
22	1975	0.2763451	0.30138	0.271513	11	0.259467	0.30296
36	1	0.33256471	0.360048	0.324367	11	0.307321	0.361798
54	0	0.40484706	0.435478	0.392323	11	0.367658	0.437381
52	0	0.39681569	0.427097	0.384772	11	0.361018	0.428987
37	0	0.33658039	0.364238	0.328143	11	0.310708	0.365999
26	0	0.29240784	0.318142	0.286615	11	0.273224	0.319775
22	0	0.2763451	0.30138	0.271513	11	0.259467	0.30296
25	0	0.28839216	0.313952	0.282839	11	0.269791	0.315572
28	0	0.30043922	0.326523	0.294165	11	0.280077	0.328182
34	1974	0.32453333	0.351667	0.316817	11	0.300535	0.353395
56	1	0.41287843	0.443859	0.399873	11	0.374281	0.445775
69	0	0.46508235	0.498337	0.448952	11	0.416943	0.500311
55	0	0.40886275	0.439669	0.396098	11	0.370971	0.441578
42	0	0.35665882	0.385191	0.347019	11	0.32758	0.387001
37	0	0.33658039	0.364238	0.328143	11	0.310708	0.365999
37	0	0.33658039	0.364238	0.328143	11	0.310708	0.365999
41	1973	0.35264314	0.381001	0.343244	11	0.324214	0.382801
53	0	0.40083137	0.431288	0.388547	11	0.36434	0.433184
64	0	0.44500392	0.477384	0.430076	11	0.400613	0.47934

55	0	0.40886275	0.439669	0.396098	11	0.370971	0.441578
42	0	0.35665882	0.385191	0.347019	11	0.32758	0.387001
42	0	0.35665882	0.385191	0.347019	11	0.32758	0.387001
43	0	0.36067451	0.389382	0.350794	11	0.330943	0.3912
41	0	0.35264314	0.381001	0.343244	11	0.324214	0.382801
39	0	0.34461176	0.37262	0.335693	11	0.317469	0.3744
46	1972	0.37272157	0.401954	0.36212	11	0.341004	0.403798
65	1	0.44901961	0.481574	0.433851	11	0.403887	0.483535
70	0	0.46909804	0.502527	0.452727	11	0.420197	0.504505
58	0	0.4209098	0.45224	0.407424	11	0.380888	0.454168
50	0	0.38878431	0.418716	0.377222	11	0.354363	0.420591
48	0	0.38075294	0.410335	0.369671	11	0.347692	0.412195
50	0	0.38878431	0.418716	0.377222	11	0.354363	0.420591
60	1971	0.42894118	0.460622	0.414974	11	0.387479	0.462559
66	0	0.45303529	0.485765	0.437626	11	0.407157	0.487729
42	0	0.35665882	0.385191	0.347019	11	0.32758	0.387001
42	0	0.35665882	0.385191	0.347019	11	0.32758	0.387001

NORTHERN PATH

SAMPLE 86
THICKNESS mm 1
SLITLENGTH mm 2
SLITWIDTH mm 0.878893
HPIXELSIZE mm 0.878893
VPIXELSIZE mm 0.878893
DATA

DENSITY	YEAR						
0	0						
0	0						
1	0						
3	0						
11	0						
35	0						
62	2002	0.43697255	0.469003	0.422525	11	0.394054	0.47095
70	0	0.46909804	0.502527	0.452727	11	0.420197	0.504505
69	2001	0.46508235	0.498337	0.448952	11	0.416943	0.500311
70	1	0.46909804	0.502527	0.452727	11	0.420197	0.504505
70	2000	0.46909804	0.502527	0.452727	11	0.420197	0.504505
70	1	0.46909804	0.502527	0.452727	11	0.420197	0.504505
70	1999	0.46909804	0.502527	0.452727	11	0.420197	0.504505
67	1	0.45705098	0.489956	0.441401	11	0.410423	0.491923
64	1998	0.44500392	0.477384	0.430076	11	0.400613	0.47934
66	0	0.45303529	0.485765	0.437626	11	0.407157	0.487729
68	1997	0.46106667	0.494146	0.445177	11	0.413685	0.496117
69	1	0.46508235	0.498337	0.448952	11	0.416943	0.500311
74	1996	0.48516078	0.51929	0.467828	11	0.433175	0.521276
76	1995	0.49319216	0.527671	0.475379	11	0.439641	0.529661
72	0	0.47712941	0.510908	0.460278	11	0.426694	0.512891
67	1994	0.45705098	0.489956	0.441401	11	0.410423	0.491923
63	0	0.44098824	0.473193	0.4263	11	0.397336	0.475145

60	1993	0.42894118	0.460622	0.414974	11	0.387479	0.462559
60	1	0.42894118	0.460622	0.414974	11	0.387479	0.462559
62	1992	0.43697255	0.469003	0.422525	11	0.394054	0.47095
61	1	0.43295686	0.464812	0.41875	11	0.390768	0.466755
66	1991	0.45303529	0.485765	0.437626	11	0.407157	0.487729
62	0	0.43697255	0.469003	0.422525	11	0.394054	0.47095
59	1990	0.42492549	0.456431	0.411199	11	0.384185	0.458364
61	0	0.43295686	0.464812	0.41875	11	0.390768	0.466755
61	1989	0.43295686	0.464812	0.41875	11	0.390768	0.466755
61	1	0.43295686	0.464812	0.41875	11	0.390768	0.466755
63	1988	0.44098824	0.473193	0.4263	11	0.397336	0.475145
63	1	0.44098824	0.473193	0.4263	11	0.397336	0.475145
62	1987	0.43697255	0.469003	0.422525	11	0.394054	0.47095
62	1	0.43697255	0.469003	0.422525	11	0.394054	0.47095
56	1986	0.41287843	0.443859	0.399873	11	0.374281	0.445775
55	1	0.40886275	0.439669	0.396098	11	0.370971	0.441578
61	1985	0.43295686	0.464812	0.41875	11	0.390768	0.466755
66	0	0.45303529	0.485765	0.437626	11	0.407157	0.487729
59	1984	0.42492549	0.456431	0.411199	11	0.384185	0.458364
55	1	0.40886275	0.439669	0.396098	11	0.370971	0.441578
56	1983	0.41287843	0.443859	0.399873	11	0.374281	0.445775
46	1	0.37272157	0.401954	0.36212	11	0.341004	0.403798
45	1	0.36870588	0.397763	0.358345	11	0.337655	0.399599
53	1982	0.40083137	0.431288	0.388547	11	0.36434	0.433184
46	1	0.37272157	0.401954	0.36212	11	0.341004	0.403798
38	1	0.34059608	0.368429	0.331918	11	0.314091	0.3702
49	1981	0.38476863	0.414525	0.373446	11	0.35103	0.416393
56	0	0.41287843	0.443859	0.399873	11	0.374281	0.445775
48	0	0.38075294	0.410335	0.369671	11	0.347692	0.412195
50	0	0.38878431	0.418716	0.377222	11	0.354363	0.420591
60	1980	0.42894118	0.460622	0.414974	11	0.387479	0.462559
60	1	0.42894118	0.460622	0.414974	11	0.387479	0.462559
59	1	0.42492549	0.456431	0.411199	11	0.384185	0.458364
66	1979	0.45303529	0.485765	0.437626	11	0.407157	0.487729
60	1	0.42894118	0.460622	0.414974	11	0.387479	0.462559
50	1	0.38878431	0.418716	0.377222	11	0.354363	0.420591
67	1978	0.45705098	0.489956	0.441401	11	0.410423	0.491923
77	0	0.49720784	0.531861	0.479154	11	0.442868	0.533853
57	0	0.41689412	0.44805	0.403649	11	0.377586	0.449971
39	0	0.34461176	0.37262	0.335693	11	0.317469	0.3744
45	1977	0.36870588	0.397763	0.358345	11	0.337655	0.399599
53	0	0.40083137	0.431288	0.388547	11	0.36434	0.433184
46	0	0.37272157	0.401954	0.36212	11	0.341004	0.403798
38	0	0.34059608	0.368429	0.331918	11	0.314091	0.3702
33	0	0.32051765	0.347476	0.313042	11	0.297136	0.349193
39	0	0.34461176	0.37262	0.335693	11	0.317469	0.3744
52	1976	0.39681569	0.427097	0.384772	11	0.361018	0.428987
50	1	0.38878431	0.418716	0.377222	11	0.354363	0.420591
37	1	0.33658039	0.364238	0.328143	11	0.310708	0.365999
28	1	0.30043922	0.326523	0.294165	11	0.280077	0.328182
22	1	0.2763451	0.30138	0.271513	11	0.259467	0.30296
20	1	0.26831373	0.292999	0.263963	11	0.252563	0.294551
30	1	0.30847059	0.334904	0.301716	11	0.286913	0.336587
53	1975	0.40083137	0.431288	0.388547	11	0.36434	0.433184
60	0	0.42894118	0.460622	0.414974	11	0.387479	0.462559

47	0	0.37673725	0.406144	0.365896	11	0.34435	0.407996
34	0	0.32453333	0.351667	0.316817	11	0.300535	0.353395
27	0	0.29642353	0.322333	0.29039	11	0.276652	0.323979
26	0	0.29240784	0.318142	0.286615	11	0.273224	0.319775
26	0	0.29240784	0.318142	0.286615	11	0.273224	0.319775
29	0	0.3044549	0.330714	0.29794	11	0.283497	0.332384
50	1974	0.38878431	0.418716	0.377222	11	0.354363	0.420591
76	0	0.49319216	0.527671	0.475379	11	0.439641	0.529661
68	0	0.46106667	0.494146	0.445177	11	0.413685	0.496117
45	0	0.36870588	0.397763	0.358345	11	0.337655	0.399599
36	0	0.33256471	0.360048	0.324367	11	0.307321	0.361798
35	0	0.32854902	0.355857	0.320592	11	0.30393	0.357597
35	0	0.32854902	0.355857	0.320592	11	0.30393	0.357597
48	1973	0.38075294	0.410335	0.369671	11	0.347692	0.412195
66	0	0.45303529	0.485765	0.437626	11	0.407157	0.487729
60	0	0.42894118	0.460622	0.414974	11	0.387479	0.462559
43	0	0.36067451	0.389382	0.350794	11	0.330943	0.3912
40	0	0.34862745	0.37681	0.339469	11	0.320844	0.378601
41	0	0.35264314	0.381001	0.343244	11	0.324214	0.382801
38	0	0.34059608	0.368429	0.331918	11	0.314091	0.3702
38	0	0.34059608	0.368429	0.331918	11	0.314091	0.3702
55	1972	0.40886275	0.439669	0.396098	11	0.370971	0.441578
71	0	0.47311373	0.506718	0.456503	11	0.423447	0.508698
67	0	0.45705098	0.489956	0.441401	11	0.410423	0.491923
56	0	0.41287843	0.443859	0.399873	11	0.374281	0.445775
50	0	0.38878431	0.418716	0.377222	11	0.354363	0.420591
50	0	0.38878431	0.418716	0.377222	11	0.354363	0.420591
55	0	0.40886275	0.439669	0.396098	11	0.370971	0.441578
63	1971	0.44098824	0.473193	0.4263	11	0.397336	0.475145
49	1	0.38476863	0.414525	0.373446	11	0.35103	0.416393
18	1	0.26028235	0.284618	0.256412	11	0.245642	0.286141
18	1	0.26028235	0.284618	0.256412	11	0.245642	0.286141
		Mean Uncalibrated Density	Mean Calibrated Density			Mean Density at 0% MC	Mean Density at 12 MC
		0.40192825	0.432432			0.364861	0.434309
		Mean Uncalibrated Density of the last 23 pixels	Mean Calibrated Density of the last 23 pixels			Mean Density at 0% MC of the last 23 pixels	Mean Density at 12 MC of the last 23 pixels
		0.43732174	0.469367			0.394176	0.471306
		0.4565272	0.489409			0.409959	0.491374
		0.44692447	0.479388			0.402068	0.48134

Southern Path

		Uncalibrated Density	Calibrated Density		Moisture Content %	Density at 0% MC	Density at 12 MC
WINDENDRO	3						
SAMPLE	521						
THICKNESS mm	1						
SLITLENGTH mm	2						
SLITWIDTH mm	0.878893						
HPIXELSIZE mm	0.878893						
VPIXELSIZE mm	0.878893						
DATA							
DENSITY	YEAR						
0	1						
2	1						
7	1						
21	1						
65	1						
110	1						
121	2002	0.67389804	0.716246	0.636663	12.5	0.578641	0.715112
122	0	0.67791373	0.720437	0.640388	12.5	0.581716	0.719308
123	0	0.68192941	0.724627	0.644113	12.5	0.584788	0.723504
108	2001	0.62169412	0.661769	0.588239	12.5	0.538361	0.660576
90	1	0.54941176	0.586339	0.52119	12.5	0.481652	0.585105
84	2000	0.52531765	0.561195	0.49884	12.5	0.462503	0.559958
83	0	0.52130196	0.557005	0.495115	12.5	0.459299	0.555767
79	1999	0.50523922	0.540242	0.480215	12.5	0.446449	0.539006
69	0	0.46508235	0.498337	0.442966	12.5	0.414077	0.497113
61	0	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
62	1998	0.43697255	0.469003	0.416891	12.5	0.391205	0.467796
59	1	0.42492549	0.456431	0.405716	12.5	0.381348	0.455234
58	1997	0.4209098	0.45224	0.401991	12.5	0.378055	0.451046
64	0	0.44500392	0.477384	0.424341	12.5	0.397758	0.476171
63	0	0.44098824	0.473193	0.420616	12.5	0.394483	0.471984
61	1996	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
60	1	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
60	1995	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
61	1	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
57	1994	0.41689412	0.44805	0.398267	12.5	0.374759	0.446859
51	1	0.3928	0.422906	0.375917	12.5	0.354904	0.42174
57	0	0.41689412	0.44805	0.398267	12.5	0.374759	0.446859
65	1993	0.44901961	0.481574	0.428066	12.5	0.401029	0.480359
65	1	0.44901961	0.481574	0.428066	12.5	0.401029	0.480359
63	1992	0.44098824	0.473193	0.420616	12.5	0.394483	0.471984
64	1	0.44500392	0.477384	0.424341	12.5	0.397758	0.476171
68	1991	0.46106667	0.494146	0.439241	12.5	0.41082	0.492924
56	1990	0.41287843	0.443859	0.394542	12.5	0.371459	0.442673
52	1	0.39681569	0.427097	0.379642	12.5	0.358222	0.425926
60	0	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
48	0	0.38075294	0.410335	0.364742	12.5	0.344927	0.409183
44	1989	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
62	0	0.43697255	0.469003	0.416891	12.5	0.391205	0.467796
62	0	0.43697255	0.469003	0.416891	12.5	0.391205	0.467796
45	1988	0.36870588	0.397763	0.353567	12.5	0.334917	0.396626
48	1	0.38075294	0.410335	0.364742	12.5	0.344927	0.409183
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
46	0	0.37272157	0.401954	0.357292	12.5	0.338257	0.400812

		Uncalibrated Density	Calibrated Density		Moisture Content %	Density at 0% MC	Density at 12 MC
46	0	0.37272157	0.401954	0.357292	12.5	0.338257	0.400812
47	1987	0.37673725	0.406144	0.361017	12.5	0.341594	0.404997
53	1	0.40083137	0.431288	0.383367	12.5	0.361537	0.430113
62	0	0.43697255	0.469003	0.416891	12.5	0.391205	0.467796
47	0	0.37673725	0.406144	0.361017	12.5	0.341594	0.404997
44	1986	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
61	0	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
50	1985	0.38878431	0.418716	0.372192	12.5	0.351582	0.417554
66	0	0.45303529	0.485765	0.431791	12.5	0.404296	0.484548
58	0	0.4209098	0.45224	0.401991	12.5	0.378055	0.451046
44	1984	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
38	0	0.34059608	0.368429	0.327492	12.5	0.311429	0.367333
39	1983	0.34461176	0.37262	0.331217	12.5	0.314796	0.371517
53	0	0.40083137	0.431288	0.383367	12.5	0.361537	0.430113
47	0	0.37673725	0.406144	0.361017	12.5	0.341594	0.404997
29	0	0.3044549	0.330714	0.293968	12.5	0.28096	0.32968
20	0	0.26831373	0.292999	0.260443	12.5	0.250181	0.292039
24	0	0.28437647	0.309761	0.275343	12.5	0.263899	0.308767
45	1982	0.36870588	0.397763	0.353567	12.5	0.334917	0.396626
62	0	0.43697255	0.469003	0.416891	12.5	0.391205	0.467796
52	0	0.39681569	0.427097	0.379642	12.5	0.358222	0.425926
34	0	0.32453333	0.351667	0.312593	12.5	0.297925	0.350597
28	0	0.30043922	0.326523	0.290243	12.5	0.277555	0.325497
36	1981	0.33256471	0.360048	0.320043	12.5	0.304684	0.358965
53	0	0.40083137	0.431288	0.383367	12.5	0.361537	0.430113
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
40	0	0.34862745	0.37681	0.334942	12.5	0.318158	0.375702
32	0	0.31650196	0.343286	0.305143	12.5	0.29115	0.34223
26	0	0.29240784	0.318142	0.282793	12.5	0.270735	0.317132
21	0	0.27232941	0.297189	0.264168	12.5	0.253616	0.296221
24	0	0.28437647	0.309761	0.275343	12.5	0.263899	0.308767
42	1980	0.35665882	0.385191	0.342392	12.5	0.324873	0.384071
56	0	0.41287843	0.443859	0.394542	12.5	0.371459	0.442673
51	0	0.3928	0.422906	0.375917	12.5	0.354904	0.42174
43	0	0.36067451	0.389382	0.346117	12.5	0.328225	0.388256
35	0	0.32854902	0.355857	0.316318	12.5	0.301307	0.354781
27	0	0.29642353	0.322333	0.286518	12.5	0.274147	0.321314
24	0	0.28437647	0.309761	0.275343	12.5	0.263899	0.308767
31	1979	0.31248627	0.339095	0.301418	12.5	0.287757	0.338046
48	1	0.38075294	0.410335	0.364742	12.5	0.344927	0.409183
61	0	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
57	0	0.41689412	0.44805	0.398267	12.5	0.374759	0.446859
42	0	0.35665882	0.385191	0.342392	12.5	0.324873	0.384071
24	0	0.28437647	0.309761	0.275343	12.5	0.263899	0.308767
15	0	0.24823529	0.272046	0.241819	12.5	0.232947	0.271132
22	1978	0.2763451	0.30138	0.267893	12.5	0.257048	0.300403
42	1	0.35665882	0.385191	0.342392	12.5	0.324873	0.384071
56	0	0.41287843	0.443859	0.394542	12.5	0.371459	0.442673
46	0	0.37272157	0.401954	0.357292	12.5	0.338257	0.400812
31	0	0.31248627	0.339095	0.301418	12.5	0.287757	0.338046
26	0	0.29240784	0.318142	0.282793	12.5	0.270735	0.317132

		Uncalibrated Density	Calibrated Density		Moisture Content %	Density at 0% MC	Density at 12 MC
23	0	0.28036078	0.30557	0.271618	12.5	0.260475	0.304585
18	0	0.26028235	0.284618	0.252993	12.5	0.243299	0.283676
14	0	0.24421961	0.267855	0.238094	12.5	0.229488	0.266951
14	0	0.24421961	0.267855	0.238094	12.5	0.229488	0.266951
22	1977	0.2763451	0.30138	0.267893	12.5	0.257048	0.300403
40	1	0.34862745	0.37681	0.334942	12.5	0.318158	0.375702
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
52	0	0.39681569	0.427097	0.379642	12.5	0.358222	0.425926
51	0	0.3928	0.422906	0.375917	12.5	0.354904	0.42174
48	0	0.38075294	0.410335	0.364742	12.5	0.344927	0.409183
41	0	0.35264314	0.381001	0.338667	12.5	0.321518	0.379886
32	0	0.31650196	0.343286	0.305143	12.5	0.29115	0.34223
24	0	0.28437647	0.309761	0.275343	12.5	0.263899	0.308767
19	0	0.26429804	0.288808	0.256718	12.5	0.246742	0.287857
22	0	0.2763451	0.30138	0.267893	12.5	0.257048	0.300403
36	1976	0.33256471	0.360048	0.320043	12.5	0.304684	0.358965
56	1	0.41287843	0.443859	0.394542	12.5	0.371459	0.442673
65	0	0.44901961	0.481574	0.428066	12.5	0.401029	0.480359
62	0	0.43697255	0.469003	0.416891	12.5	0.391205	0.467796
60	0	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
57	0	0.41689412	0.44805	0.398267	12.5	0.374759	0.446859
48	0	0.38075294	0.410335	0.364742	12.5	0.344927	0.409183
36	0	0.33256471	0.360048	0.320043	12.5	0.304684	0.358965
26	0	0.29240784	0.318142	0.282793	12.5	0.270735	0.317132
19	0	0.26429804	0.288808	0.256718	12.5	0.246742	0.287857
14	0	0.24421961	0.267855	0.238094	12.5	0.229488	0.266951
13	0	0.24020392	0.263665	0.234369	12.5	0.226025	0.26277
19	0	0.26429804	0.288808	0.256718	12.5	0.246742	0.287857
40	1975	0.34862745	0.37681	0.334942	12.5	0.318158	0.375702
68	1	0.46106667	0.494146	0.439241	12.5	0.41082	0.492924
79	0	0.50523922	0.540242	0.480215	12.5	0.446449	0.539006
73	0	0.4811451	0.515099	0.457866	12.5	0.427068	0.513868
60	0	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
46	0	0.37272157	0.401954	0.357292	12.5	0.338257	0.400812
37	0	0.33658039	0.364238	0.323768	12.5	0.308059	0.363149
33	0	0.32051765	0.347476	0.308868	12.5	0.294539	0.346413
33	0	0.32051765	0.347476	0.308868	12.5	0.294539	0.346413
33	0	0.32051765	0.347476	0.308868	12.5	0.294539	0.346413
28	0	0.30043922	0.326523	0.290243	12.5	0.277555	0.325497
25	0	0.28839216	0.313952	0.279068	12.5	0.267319	0.312949
37	1974	0.33658039	0.364238	0.323768	12.5	0.308059	0.363149
60	1	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
66	0	0.45303529	0.485765	0.431791	12.5	0.404296	0.484548
52	0	0.39681569	0.427097	0.379642	12.5	0.358222	0.425926
38	0	0.34059608	0.368429	0.327492	12.5	0.311429	0.367333
28	0	0.30043922	0.326523	0.290243	12.5	0.277555	0.325497
21	0	0.27232941	0.297189	0.264168	12.5	0.253616	0.296221
19	0	0.26429804	0.288808	0.256718	12.5	0.246742	0.287857
19	0	0.26429804	0.288808	0.256718	12.5	0.246742	0.287857
20	0	0.26831373	0.292999	0.260443	12.5	0.250181	0.292039
26	1973	0.29240784	0.318142	0.282793	12.5	0.270735	0.317132
42	1	0.35665882	0.385191	0.342392	12.5	0.324873	0.384071
64	0	0.44500392	0.477384	0.424341	12.5	0.397758	0.476171

		Uncalibrated Density	Calibrated Density		Moisture Content %	Density at 0% MC	Density at 12 MC
66	0	0.45303529	0.485765	0.431791	12.5	0.404296	0.484548
53	0	0.40083137	0.431288	0.383367	12.5	0.361537	0.430113
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
60	0	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
57	0	0.41689412	0.44805	0.398267	12.5	0.374759	0.446859
44	0	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
38	1972	0.34059608	0.368429	0.327492	12.5	0.311429	0.367333
55	1	0.40886275	0.439669	0.390817	12.5	0.368155	0.438486
72	0	0.47712941	0.510908	0.454141	12.5	0.423826	0.509679
67	0	0.45705098	0.489956	0.435516	12.5	0.40756	0.488736
56	0	0.41287843	0.443859	0.394542	12.5	0.371459	0.442673
51	0	0.3928	0.422906	0.375917	12.5	0.354904	0.42174
56	1971	0.41287843	0.443859	0.394542	12.5	0.371459	0.442673
78	1	0.50122353	0.536052	0.476491	12.5	0.443227	0.534816
87	0	0.53736471	0.573767	0.510015	12.5	0.472093	0.572531
74	0	0.48516078	0.51929	0.461591	12.5	0.430307	0.518058
52	0	0.39681569	0.427097	0.379642	12.5	0.358222	0.425926
18	0	0.26028235	0.284618	0.252993	12.5	0.243299	0.283676
18	0	0.26028235	0.284618	0.252993	12.5	0.243299	0.283676

Northern Path

SAMPLE	521						
THICKNESS mm	1						
SLITLENGTH mm	2						
SLITWIDTH mm	0.878893						
HPIXELSIZE mm	0.878893						
VPIXELSIZE mm	0.878893						
DATA							
DENSITY	YEAR						
0	0						
1	0						
5	0						
16	0						
49	0						
97	0						
121	0						
117	0						
97	0						
62	0						
56	0						
89	0						
101	2002	0.59358431	0.632435	0.562164	12.5	0.516438	0.631221
87	2001	0.53736471	0.573767	0.510015	12.5	0.472093	0.572531
72	0	0.47712941	0.510908	0.454141	12.5	0.423826	0.509679
66	2000	0.45303529	0.485765	0.431791	12.5	0.404296	0.484548
67	0	0.45705098	0.489956	0.435516	12.5	0.40756	0.488736
61	1999	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
51	1	0.3928	0.422906	0.375917	12.5	0.354904	0.42174
54	1998	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299

		Uncalibrated Density	Calibrated Density		Moisture Content %	Density at 0% MC	Density at 12 MC
63	0	0.44098824	0.473193	0.420616	12.5	0.394483	0.471984
64	1997	0.44500392	0.477384	0.424341	12.5	0.397758	0.476171
62	1	0.43697255	0.469003	0.416891	12.5	0.391205	0.467796
62	1996	0.43697255	0.469003	0.416891	12.5	0.391205	0.467796
61	1	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
63	1995	0.44098824	0.473193	0.420616	12.5	0.394483	0.471984
65	1994	0.44901961	0.481574	0.428066	12.5	0.401029	0.480359
60	0	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
61	0	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
73	1993	0.4811451	0.515099	0.457866	12.5	0.427068	0.513868
72	1	0.47712941	0.510908	0.454141	12.5	0.423826	0.509679
66	1992	0.45303529	0.485765	0.431791	12.5	0.404296	0.484548
66	1	0.45303529	0.485765	0.431791	12.5	0.404296	0.484548
68	1991	0.46106667	0.494146	0.439241	12.5	0.41082	0.492924
65	1	0.44901961	0.481574	0.428066	12.5	0.401029	0.480359
53	1	0.40083137	0.431288	0.383367	12.5	0.361537	0.430113
55	1990	0.40886275	0.439669	0.390817	12.5	0.368155	0.438486
58	0	0.4209098	0.45224	0.401991	12.5	0.378055	0.451046
58	1989	0.4209098	0.45224	0.401991	12.5	0.378055	0.451046
64	0	0.44500392	0.477384	0.424341	12.5	0.397758	0.476171
56	0	0.41287843	0.443859	0.394542	12.5	0.371459	0.442673
43	1988	0.36067451	0.389382	0.346117	12.5	0.328225	0.388256
44	1	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
46	0	0.37272157	0.401954	0.357292	12.5	0.338257	0.400812
43	0	0.36067451	0.389382	0.346117	12.5	0.328225	0.388256
43	1987	0.36067451	0.389382	0.346117	12.5	0.328225	0.388256
52	1	0.39681569	0.427097	0.379642	12.5	0.358222	0.425926
56	0	0.41287843	0.443859	0.394542	12.5	0.371459	0.442673
45	1986	0.36870588	0.397763	0.353567	12.5	0.334917	0.396626
47	1	0.37673725	0.406144	0.361017	12.5	0.341594	0.404997
56	0	0.41287843	0.443859	0.394542	12.5	0.371459	0.442673
47	0	0.37673725	0.406144	0.361017	12.5	0.341594	0.404997
44	1985	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
60	0	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
58	0	0.4209098	0.45224	0.401991	12.5	0.378055	0.451046
41	0	0.35264314	0.381001	0.338667	12.5	0.321518	0.379886
51	1984	0.3928	0.422906	0.375917	12.5	0.354904	0.42174
64	0	0.44500392	0.477384	0.424341	12.5	0.397758	0.476171
48	0	0.38075294	0.410335	0.364742	12.5	0.344927	0.409183
32	0	0.31650196	0.343286	0.305143	12.5	0.29115	0.34223
43	1983	0.36067451	0.389382	0.346117	12.5	0.328225	0.388256
60	0	0.42894118	0.460622	0.409441	12.5	0.384637	0.459421
51	0	0.3928	0.422906	0.375917	12.5	0.354904	0.42174
29	0	0.3044549	0.330714	0.293968	12.5	0.28096	0.32968
18	0	0.26028235	0.284618	0.252993	12.5	0.243299	0.283676
25	1982	0.28839216	0.313952	0.279068	12.5	0.267319	0.312949
49	1	0.38476863	0.414525	0.368467	12.5	0.348256	0.413368
63	0	0.44098824	0.473193	0.420616	12.5	0.394483	0.471984
51	0	0.3928	0.422906	0.375917	12.5	0.354904	0.42174
34	0	0.32453333	0.351667	0.312593	12.5	0.297925	0.350597
25	0	0.28839216	0.313952	0.279068	12.5	0.267319	0.312949
32	0	0.31650196	0.343286	0.305143	12.5	0.29115	0.34223
58	1981	0.4209098	0.45224	0.401991	12.5	0.378055	0.451046
66	0	0.45303529	0.485765	0.431791	12.5	0.404296	0.484548

		Uncalibrated Density	Calibrated Density		Moisture Content %	Density at 0% MC	Density at 12 MC
47	0	0.37673725	0.406144	0.361017	12.5	0.341594	0.404997
32	0	0.31650196	0.343286	0.305143	12.5	0.29115	0.34223
24	0	0.28437647	0.309761	0.275343	12.5	0.263899	0.308767
24	1980	0.28437647	0.309761	0.275343	12.5	0.263899	0.308767
38	1	0.34059608	0.368429	0.327492	12.5	0.311429	0.367333
49	0	0.38476863	0.414525	0.368467	12.5	0.348256	0.413368
44	0	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
32	0	0.31650196	0.343286	0.305143	12.5	0.29115	0.34223
24	0	0.28437647	0.309761	0.275343	12.5	0.263899	0.308767
23	0	0.28036078	0.30557	0.271618	12.5	0.260475	0.304585
27	0	0.29642353	0.322333	0.286518	12.5	0.274147	0.321314
41	1979	0.35264314	0.381001	0.338667	12.5	0.321518	0.379886
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
53	0	0.40083137	0.431288	0.383367	12.5	0.361537	0.430113
42	0	0.35665882	0.385191	0.342392	12.5	0.324873	0.384071
28	0	0.30043922	0.326523	0.290243	12.5	0.277555	0.325497
20	0	0.26831373	0.292999	0.260443	12.5	0.250181	0.292039
22	0	0.2763451	0.30138	0.267893	12.5	0.257048	0.300403
32	0	0.31650196	0.343286	0.305143	12.5	0.29115	0.34223
53	1978	0.40083137	0.431288	0.383367	12.5	0.361537	0.430113
57	0	0.41689412	0.44805	0.398267	12.5	0.374759	0.446859
38	0	0.34059608	0.368429	0.327492	12.5	0.311429	0.367333
24	0	0.28437647	0.309761	0.275343	12.5	0.263899	0.308767
21	0	0.27232941	0.297189	0.264168	12.5	0.253616	0.296221
20	0	0.26831373	0.292999	0.260443	12.5	0.250181	0.292039
18	0	0.26028235	0.284618	0.252993	12.5	0.243299	0.283676
16	0	0.25225098	0.276237	0.245544	12.5	0.236401	0.275313
19	1977	0.26429804	0.288808	0.256718	12.5	0.246742	0.287857
32	1	0.31650196	0.343286	0.305143	12.5	0.29115	0.34223
47	0	0.37673725	0.406144	0.361017	12.5	0.341594	0.404997
43	0	0.36067451	0.389382	0.346117	12.5	0.328225	0.388256
31	0	0.31248627	0.339095	0.301418	12.5	0.287757	0.338046
27	0	0.29642353	0.322333	0.286518	12.5	0.274147	0.321314
26	0	0.29240784	0.318142	0.282793	12.5	0.270735	0.317132
21	0	0.27232941	0.297189	0.264168	12.5	0.253616	0.296221
18	0	0.26028235	0.284618	0.252993	12.5	0.243299	0.283676
17	0	0.25626667	0.280427	0.249269	12.5	0.239852	0.279494
17	0	0.25626667	0.280427	0.249269	12.5	0.239852	0.279494
23	0	0.28036078	0.30557	0.271618	12.5	0.260475	0.304585
42	1976	0.35665882	0.385191	0.342392	12.5	0.324873	0.384071
58	0	0.4209098	0.45224	0.401991	12.5	0.378055	0.451046
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299
43	0	0.36067451	0.389382	0.346117	12.5	0.328225	0.388256
37	0	0.33658039	0.364238	0.323768	12.5	0.308059	0.363149
29	0	0.3044549	0.330714	0.293968	12.5	0.28096	0.32968
21	0	0.27232941	0.297189	0.264168	12.5	0.253616	0.296221
17	0	0.25626667	0.280427	0.249269	12.5	0.239852	0.279494
15	0	0.24823529	0.272046	0.241819	12.5	0.232947	0.271132
13	0	0.24020392	0.263665	0.234369	12.5	0.226025	0.26277
18	1975	0.26028235	0.284618	0.252993	12.5	0.243299	0.283676
38	1	0.34059608	0.368429	0.327492	12.5	0.311429	0.367333
59	0	0.42492549	0.456431	0.405716	12.5	0.381348	0.455234
61	0	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
54	0	0.40484706	0.435478	0.387092	12.5	0.364848	0.434299

		Uncalibrated Density	Calibrated Density		Moisture Content %	Density at 0% MC	Density at 12 MC
44	0	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
33	0	0.32051765	0.347476	0.308868	12.5	0.294539	0.346413
29	0	0.3044549	0.330714	0.293968	12.5	0.28096	0.32968
33	0	0.32051765	0.347476	0.308868	12.5	0.294539	0.346413
34	0	0.32453333	0.351667	0.312593	12.5	0.297925	0.350597
31	0	0.31248627	0.339095	0.301418	12.5	0.287757	0.338046
44	1974	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
73	1	0.4811451	0.515099	0.457866	12.5	0.427068	0.513868
78	0	0.50122353	0.536052	0.476491	12.5	0.443227	0.534816
61	0	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
44	0	0.3646902	0.393572	0.349842	12.5	0.331572	0.392441
32	0	0.31650196	0.343286	0.305143	12.5	0.29115	0.34223
29	0	0.3044549	0.330714	0.293968	12.5	0.28096	0.32968
31	0	0.31248627	0.339095	0.301418	12.5	0.287757	0.338046
37	0	0.33658039	0.364238	0.323768	12.5	0.308059	0.363149
59	1973	0.42492549	0.456431	0.405716	12.5	0.381348	0.455234
77	0	0.49720784	0.531861	0.472766	12.5	0.440003	0.530626
68	0	0.46106667	0.494146	0.439241	12.5	0.41082	0.492924
61	0	0.43295686	0.464812	0.413166	12.5	0.387923	0.463608
67	0	0.45705098	0.489956	0.435516	12.5	0.40756	0.488736
65	0	0.44901961	0.481574	0.428066	12.5	0.401029	0.480359
59	1972	0.42492549	0.456431	0.405716	12.5	0.381348	0.455234
75	1	0.48917647	0.52348	0.465316	12.5	0.433543	0.522247
91	0	0.55342745	0.590529	0.524915	12.5	0.484832	0.589297
85	0	0.52933333	0.565386	0.502565	12.5	0.465703	0.564149
80	0	0.5092549	0.544433	0.48394	12.5	0.449667	0.543196
88	0	0.54138039	0.577958	0.51374	12.5	0.475283	0.576722
105	1971	0.60964706	0.649197	0.577064	12.5	0.528986	0.647995
99	1	0.58555294	0.624054	0.554714	12.5	0.510144	0.622835
57	1	0.41689412	0.44805	0.398267	12.5	0.374759	0.446859
15	1	0.24823529	0.272046	0.241819	12.5	0.232947	0.271132
15	1	0.24823529	0.272046	0.241819	12.5	0.232947	0.271132

	Mean Uncalibrated Density	Mean Calibrated Density	Mean Density at 0% MC	Mean Density at 12 MC
	0.37984203	0.40712	0.341636	0.406

	Mean Uncalibrated Density of the last 23 pixels	Mean Calibrated Density of the last 23 pixels	Mean Density at 0% MC of the last 23 pixels	Mean Density at 12 MC of the last 23 pixels
South	0.48795431	0.522205	0.431688	0.521007
North	0.45513043	0.487951	0.40582	0.48674

	Uncalibrated Density	Calibrated Density		Moisture Content %	Density at 0% MC	Density at 12 MC
Combined	0.47154237	0.505078			0.418754	0.503873