Assessing The Asymmetry Of Kauri Stem: The Development Of A Pith Locator Method

Author:
Maryann Pirie
Supervisors:
Dr. A Fowler,
Prof. C. Triggs
Department of Statistics and School of Environment
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Abstract

Estimation of the distance from the chorological centre of a tree to the inner ring on a core (pith offset) is used in many areas of Dendroclimatology. One of the methods used in the estimation of pith offsets is the radius-length method. This method relies on the assumption that the pith is located at the geometric centre of the stem that fails if the stem is asymmetric. A method of assessing the asymmetry, called 'pith locator', was developed. The pith locator method and kauri cross-sections provide evidence of asymmetry in kauri. This asymmetry can result in significant errors in estimated pith offsets when the radius-length method is used.

Introduction

Allen (1988), Clayton-Green (1977), Norton et al. (1987) and Wardle (1963) based their age estimations of New Zealand trees on the assumption that the chronological centre of the tree is near the geometric centre. They then estimated the pith offset as the distance from the innermost ring on the incremental core to the geometric centre. This process is known as the 'radius-length' method for estimating pith offsets. However, this assumption is known to be flawed as the rings on the cross-sections taken from two seedlings of *L. bidwillii* sampled by Clayton-Greene (1977) were not completely concentric and Norton et al (1987) noted that the geometric centre can differ from the chronological centre (or pith) when the stem is asymmetric or when the rings are eccentric. If the pith is not located at the geometric centre then the 'radius-length' method may either under or over estimate the true distance to the pith.

This analysis uses cores from living kauri to test the assumption that the pith is located near to the geometric centre. This is achieved through the development a method to find the location of the pith using two or more cores. Once the location has been estimated then the asymmetry of the stem of kauri at coring height is investigated.

Method

Basic model

For the basic model (Figure 1) the location of the pith can be estimated if three conditions are met:

- The exact bearing is known
- The corer is aimed directly towards the geometric centre of the tree.
- The core shows a complete arc.

If these pre-conditions are met then the measurements and calculations are required:

- Distance to the centre of the arc of the inner most ring on the core (Doa) is measured,
- Distance to the pith from the inner most ring, pith offset (Dpa), is estimated using Duncan's geometric model.
- Distance to the pith from the outer edge of the cross-section (Dpo) is calculated from Doa and Dpa using simple geometry.

Allowing for error in aim of corer

When coring trees, normal practice is to aim the corer towards the geometric centre of the tree. However, errors can arise when aiming the corer. The basic model is extended to account for error in the aim of the core. The location of the estimated pith if the error aim of the corer is ±5° is shown in Figure 2.

Allowing for Error in bearing

For the cores, the bearing was either recorded using a quadrant bearing (such as, N, NE, E,..) or an azimuth bearing (in degrees). When using a quadrant bearing the error would reasonably be ±22.5°. When the bearing is an azimuth bearing then this error should be smaller, because it is a more precise measurement. Figure 3 shows an extension of the basic model to allow for error in the bearing of the corer and the location of the estimated pith when the error in the bearing is ± 15 °.

Combining aim and bearing errors

In practice errors in both aim and bearing occur. Allowing for both errors produces an estimation region where the true-pith will occur (Figure 4), this is referred to as the 'pith region' for a core. This region is bounded by four curves. The main features of these curves are:

1. If the bearing is unknown, pith region would form a ring about the geometric centre. The width of this ring is a function of the error in aim.
2. When the bearing error is known then the rings is reduced to a area (purple curves). The angle created by the ends of this arc and the geometric centre is two times the bearing error.
3. The length of the ends (green curves) are a function of the aim error. As the error in bearing is increased these curves are swept around the geometric centre.

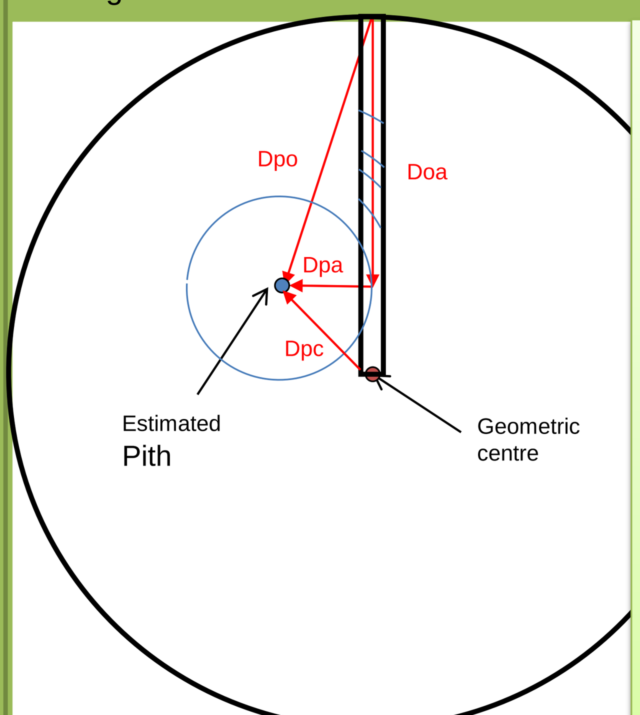

Figure 1: *Illustration of the basic model of the pith locator method for a single core. This presents a cross-section; core is aimed directly at the geometric centre. The inner rings of this core is a complete arc. From this core the position of the pith is estimated. Dpo = Distance from outside edge to pith, Dpa = Distance from arc to pith (pith offset), Doa = Distance from outside edge to arc, and Dpc = Distance from pith to geometric centre.*

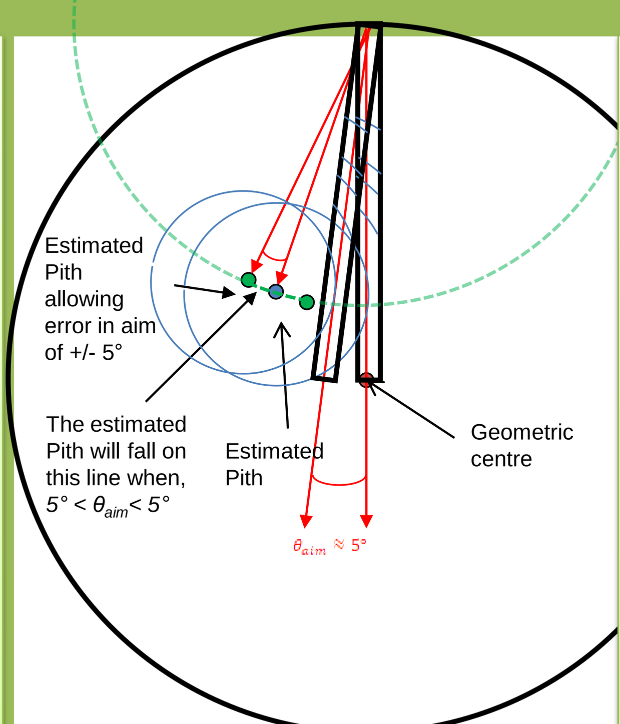

Figure 2: *Demonstration of the extension of the basic model to account for error in Aim of corer. Shown is the estimated pith under the basic model and position of the estimated pith when the corer aimed up to± 5° off the direct line to the geometric centre. When the error in aim is unknown then the estimated pith will fall on the dashed line.*

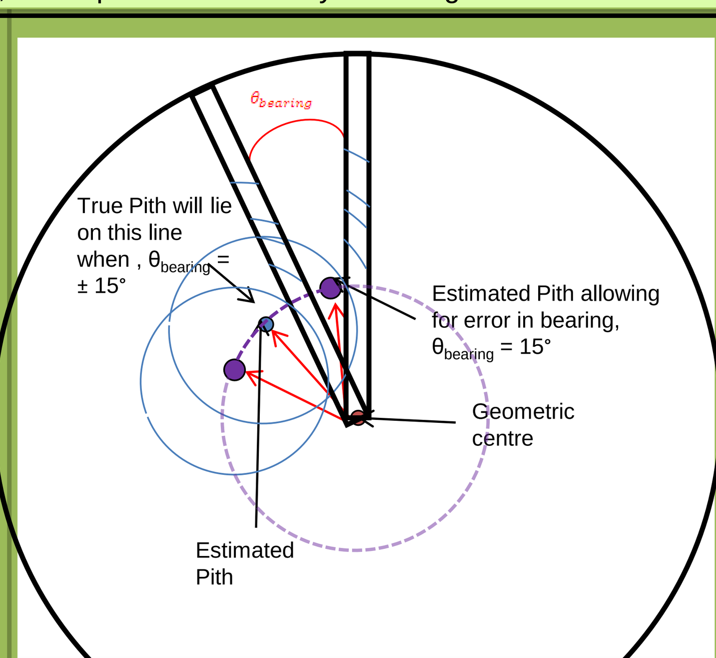

Figure 3: *Illustration the extension of the basic model to allow for errors in the bearing. Shown is the location of the estimated pith under the basic model and when there is error in the bearing. If the error in bearing is unknown then the pith will fall on the dashed circle. Error in aim is not considered in this figure.*

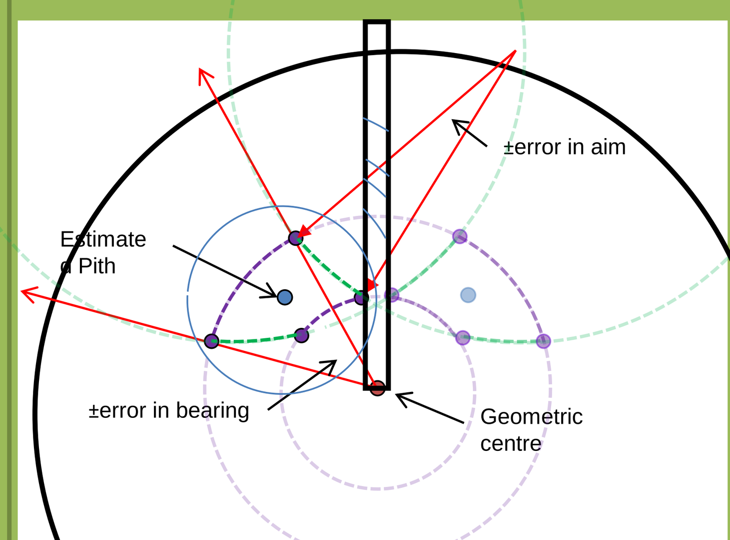

Figure 4: *The basic model for the pith region extended to include both errors in bearing and aim. This produces a region between the 4 curves. This region indicates where the pith should be located when allowing for errors in the bearing and aim of the corer towards the geometric centre. The pale purple circle shows the resultant ring if the bearing is unknown. The pale green arcs show the curves produced if the aim error is unknown. The region to the right becomes the pith region when the rings arc towards the right. Both regions are drawn when the orientation of the core is unknown.*

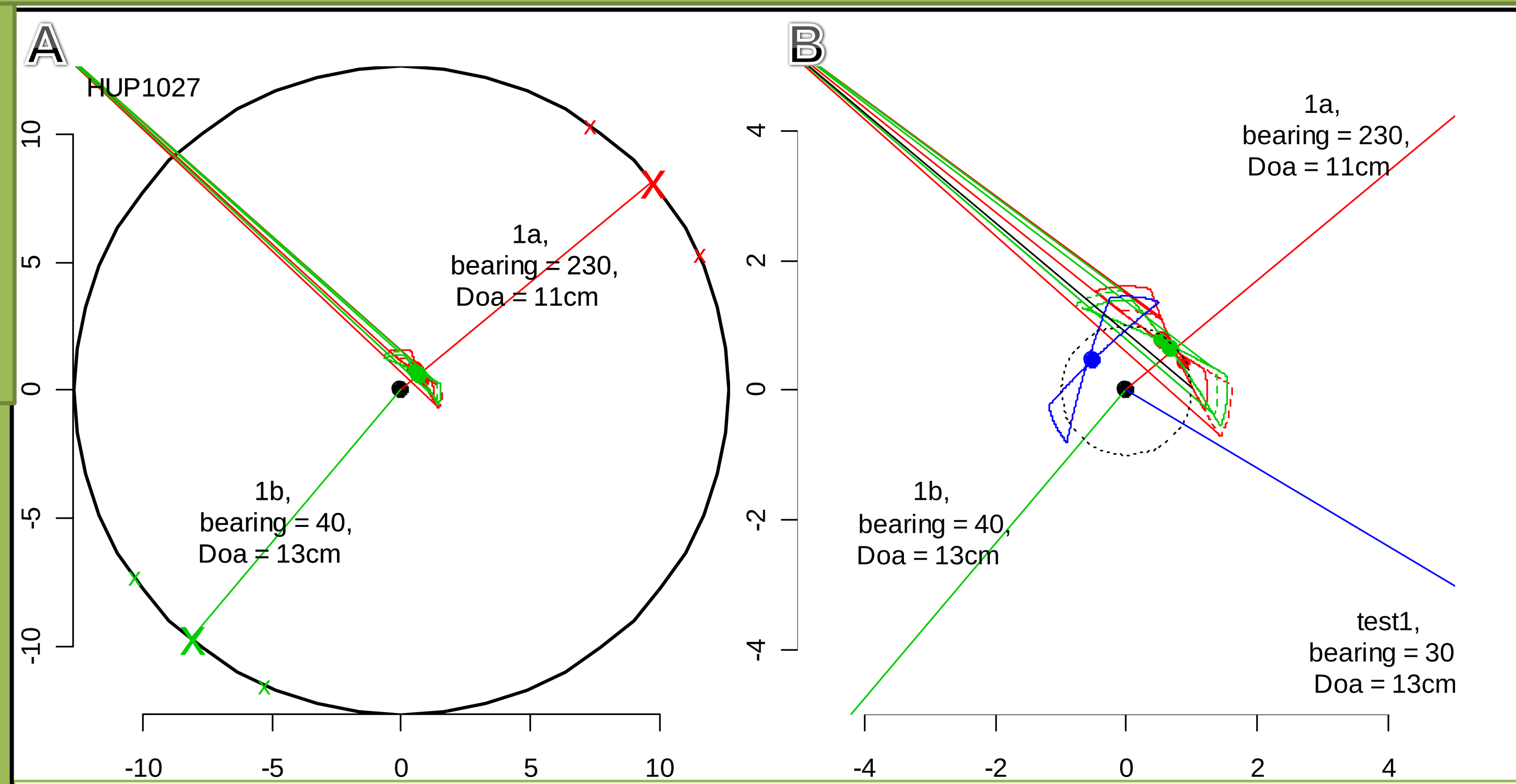

Figure 5: Pith locator diagram to illustrate the estimated position of the pith and the pith region for tree HUP1027. A: For core 1a the red line is the assumed position of the core, the red dot is the estimated position of the pith, the red 'X' is the bearing, the 'x' the bearing ±15°, and the red shape is the pith region for core. The bold region is the pith region assuming the core is orientated to the right, and the dashed line is for the core orientated to the left. Similarly, the green line and shape for core 1b. B: The pith locator diagram for tree HUP1027 with the inclusion of a third test core (blue). The orientation is known to be to the right of the core, therefore only one shape drawn. The circle illustrates the cross section of the tree and the diameter of the circle is equal to the DCH. The dashed circle, centred at the geometric centre and has a radius of 1cm, this is provided for clarity. The length of the core has been corrected for drying.

Eccentricity Ratio

To compare the symmetry of the cross-section from different trees a measure of stem eccentricity is required. The eccentricity ratio is defined as the :

Distance from the geometric centre to pith divided by the radius of the tree.

This is similar to the measure of eccentricity presented by Akachuku and Abolarin (1989). An eccentricity ratio of 0 means that the estimated pith is located at the geometric centre. A value of 1 indicates that the estimated pith is located on the outside edge of the cross-section; which is implausible.

Table 1: *Eccentricity ratio for the display cross-section and the photograph.*

	Diameter	Eccentricity Ratio
Display Piece	8cm	0.09
	17cm	0.05
	43cm	0.06
	110cm	0.16
Photograph	14 units	0.14
	7.3 units	0.12
	3.2 units	0.18

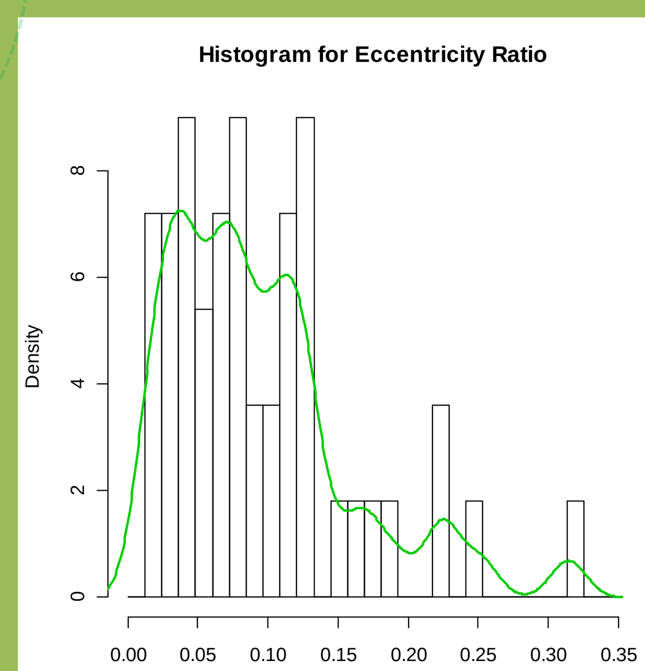

Figure 8: Histogram of the eccentricity ratio for the 18 kauri trees. With smoothed density, green line. The smoothed density line suggests that there is one peak that occurs from 0.02 to 0.13.

Application

The pith locator method is demonstrated for Huapai tree 1027 (HUP1027) in Figure 5. This small tree (diameter at coring height (DCH) equals 25.3cm) is located on a north facing slope of the East Ridge at Huapai. Two cores were obtained from the tree on September 2008 (1a, 1b).

The first core, 1a, has a bearing of 230° and length to the arc of 11.4cm. The vertical orientation for this core is unknown, therefore the estimated location of the pith and pith region is provided for both orientations (2 dots, and 2 regions). The pith offset is relatively smaller than the error in the aim, as evidenced by the 'bow tie' shape of the pith region. This is a result of the estimated pith occurring close to the core, and the inclusion of the aim and bearing errors means that the pith could occur on either side of the assumed location of the core under the basic model.

This core is shorter than the radius therefore the pith region occurs before the geometric centre. Using the model the pith would be expected to occur between NW and SE of the geometric centre at an estimated distance of 0.96cm; the errors are shown by the pith region (the greatest distance from the geometric centre is 1.6cm).

The second core, 1b, has a bearing of 40° and the length to the arc is 0.92cm (Figure 5A, shown in green). The vertical orientation of this core is unknown. Because the distance from the outside of the tree to the arc is greater than the radius of the tree, the estimated pith occurs after the geometric centre. Using only this core, the pith would be estimated to occur between NW and SE of the geometric centre, at a distance of approximately 0.56cm, with errors indicated by the pith region (greatest point of this region from the geometric centre is 0.15cm).

A third core, test1, was sampled at a bearing of 301° (Figure 5B). The core was aimed at the geometric centre with the expectation that the pith would be close to (~1cm) and located to the right of the core. The pith was not visible for the test1 core The distance to the arc was 13cm and the vertical orientation of this core was marked at time of coring, therefore the arcing of the rings indicate that the pith is located to the right of the core; supporting the assumption. The assumed position of the core and estimated pith from the basic model and the estimated pith region are indicated by the blue line and dots. Using only this core, the pith is expected to be between NW to NE at a distance of 0.71cm, with error in the distance and location shown by the pith region (max. distance from geometric centre 1.5cm).

Combined information from all three cores provides details on the location of the true pith. The pith region of the core test1 overlaps the northern side of the pith region of the cores 1a and 1b. Therefore, it is highly likely that the true pith will be located within these overlapping regions. The position of the true pith has a high probability of occurring between NNW and NNE from the geometric centre at a distance of 1 to 1.5cm.

Evidence of Asymmetry in Kauri

Kauri has the potential to have an asymmetric stem, as evidenced by Kauri cross-sections seen in historical photographs and display pieces. Asymmetry is further supported by the pith locator method when applied to 18 trees from Huapai Scientific Reserve.

Historical photographic records, taken during the milling of kauri, provide evidence of asymmetry (Figure 6). The eccentricity ratio for this cross section is 0.14 (from photograph: the diameter is 14 units; distance from the geometric centre to the pith, Dpc, is 1), assuming that the circumference, geometric centre and pith are indicated by the blue circles and lines.

The eccentricity ratio for a kauri cross-section (Figure 7) , a display piece held at the Tree ring Lab, University of Auckland, is 0.16 . The stem eccentricity is related to the size of the tree (Table 1). The cross-section becomes asymmetric as the diameter of the tree increases whereas, for the photographic record , the cross-section becomes slightly less asymmetric as the diameter increases.

The eccentric ratios provided by the pith locator method for the 18 kauri trees at Huapai were similar to those provided by the historical photograph and display piece. Most of the cores estimated the eccentricity ratio to be less than 0.2, suggesting that in most cases, the estimated pith was near to the geometric centre of the tree. However, for tree HUP1062 the eccentricity ratio was 0.34, indicating that the estimated pith was far from the geometric centre for this tree.

Figure 6: *Historical Photograph of a kauri cross-section. The blue line and circles shows the circumference, geometric centre, and the location of the pith. These were used to calculate the eccentricity ratio for this cross-section. The red line is used to calculated the distance from the geometric centre to the pith. Source: The Kauri Cameraman.*

Conclusion

There is some evidence of asymmetry in kauri stem as indicated by the display piece, historical photograph and the pith locator method. The pith locator method provided a method of estimating the position of the pith and the errors associated with this estimate. Reducing the errors in the aim and bearing when coring will improve the estimation of the pith location. Bearing error has the greatest effect on the eccentricity ratio. Therefore the eccentricity ratio for the18 kauri trees could be, allowing for error, greater or smaller than shown. Asymmetry of the stem results in significant errors in the pith offset estimation when using the radius-length method. It is recommended that these errors are considered.

Figure 7: *Photograph of kauri cross section. Blue circle shows circumference for calculating eccentricity ratio, the geometric centre is located where the two blue lines intersect. The Red line, indicates the distance from the geometric centre to the pith. M Pirie, Tree ring Lab, University of Auckland.*

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