# Ground-level remote DBH measurement

Typical mixed age and species Eucalypt forests of northeast NSW Australia, where the BlueChip Tree Tools ™ were developed and tested. I now employ these tools routinely for forest inventory.

*Key words ; dendrometry, diameter at breast height, DBH , measurement, remote measurement, optical caliper, optical fork, forest inventory, timber cruise, ecological survey, belt transect, distance, low-cost forestry tools , forestry mensuration, instruments for DBH measurement, BlueChip Tree Tools*

# Ground-level remote DBH measurement

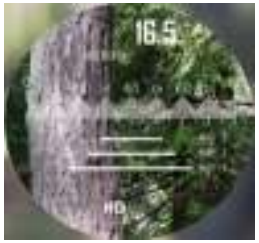
- Diameter at breast height (DBH), 1.3m above ground, is an important descriptor of trees and widely used for forest inventory and ecological surveys.
- The field cost of inventory is reduced if accurate DBH measures can be made from a distance instead of at the tree. Also, biomass and timber volume estimates can be made more accurately and at lower cost for individual trees if fast and safe measures of height and diameter in the upper bole are available without climbing.
- "BlueChip Tree Tools" ™
- The following article introduces several low-cost light weight and easily portable tools which I have designed and made for measuring tree diameter at a distance. A low-cost, super compact, tree height and log length measuring tool is also described. The tools are a combinations of various off-the-shelf components, cameras, lenses, tapes, laser pens, aluminium rail, glue, screws and so forth. These tools are easy to use and calibrate on the fly, and sufficiently robust for field usage in most conditions. Batteries are required for some of these tools, and the user must have fair eyesight.
- The methods and tools suit trees with DBH 10-120cm at most practical distances, eg 5-50m. Precision and accuracy are sufficient for errors <2%, eg DBH 50cm +/- 1cm.
- Methods require direct or interpolated line of sight to DBH. All usual lighting conditions of forest during daylight are accommodated by choosing an appropriate tool.

- A good discussion of principles underlying some of the dendrometry methods described here can be found in the review by Clark, Wynne and Schmoldt, 2000. A Review of Past Research on Dendrometers Forest Science 46(4) : 570-576 http://www.researchgate.net/profile/Randolph_Wynne/publication/225076673_A_review_of_past_research_on_dendrometers/links/0912f50981a54ef5b5000000
- These authors reviewed a number of commercial instruments and adaptations used in dendrometry at that time. They considered that film cameras were impractical, and the digital cameras available at the time were not accurate enough with their limited optics and resolution. They also noted that handcrafted optical forks were the least expensive instruments, but that accuracy was limited for these (and cameras) because they required distance measures which were imprecise unless a marker or tape was held in contact at the tree (which of course defeats the purpose of remote DBH measure). Laser range finders are mentioned briefly but were too expensive for routine use at the time. The authors considered that the most precise non-contact dendrometers were those which relied on coincident images from magnifying optics and did not require distance measures (eg Barr and Stroud dendrometer, Wheeler pentaprism caliper, McClure mirror caliper, Zeiss Telemeter pictured L->R below)). However these instruments were cumbersome to carry and use in practice, limited by line of sight obstructions, difficult to use in poor lighting, expensive (except McClure caliper), and able to measure only to limited size (~60cm DBH). Except for the pentaprism caliper (~USD $650 in 2014), these instruments are no longer in manufacture because of the limited market and high cost.

Some off-the-shelf tools currently available for remote and upper stem diameter measurement are shown below. (Image are from manufacturers web pages as linked). L→R these are

- **Relaskop**, and TeleRelaskop with 5x or 8x lens http://relaskop.at/en/
- **RD 1000** costs c. USD $1500, plus additional $500-$1500 for laser rangefinder http://www.lasertech.com/Criterion-RD-1000.aspx , http://www.breithaupt.de/en/products
- **Leica Disto** red dot range finder with built in camera and sliding scale ; cost c. USD $1000 http://disto.com.au/products/distod810.htm
- **TruPulse 360** http://www.lasertech.com/TruPulse-Laser-Rangefinder.aspx costs c. USD $1600 Uses horizontal angle differences to obtain diameter, or fitted with custom reticle. http://www.field-map.com/files/trupulsedendroscope.pdf

The first two instruments require independent measures of distance. All work best if mounted on a tripod for accuracy. On the first two, the reading scales can be confusing or difficult to use in low light or on trees with dark bark, and may require some interpolation by the user, (eg counting of light bands or alternating B&W stripes) which can create reading errors. They appear to offer accuracy similar to the BlueChip Tree Tools ™ described in the following pages, although at greater cost.


# “BlueChip Tree Tools” ™

1. Distance meters
2. Laser bar caliper
3. Optical fork;  handheld digital caliper
4. Monocular with scale
5. Digital camera
6. iPhone “Theodolite” app
7. Height

Designed for use in mixed species native forest inventory, using BA sweep points with BAF2.

Tested in open-dense wet and dry native Eucalypt forest of northeast NSW, with trees of 10-120cm DBH which are measured at distances 5-40m.

# Distance meters

- The availability of portable, affordable and accurate laser rangefinders makes methods available which were previously impractical.
- First shown is a handheld red dot (450nm) laser meter, equipped with extra LED red dot sighting mechanism. Sighting can be easily aligned during usage.
- Range is listed as 70m. In practice 25m is the limit for tree trunks in bright sunlit conditions, with up to 50m on tree bark in moderate shade.
- Precision : xx.xxx m,  accuracy +/- 2mm.
- With steady hands while sighting the instrument held against eye,  it is possible to aim the red dot consistently to a target point of c.10cm diameter at 50m distance and obtain consistent readings off both dark and light coloured tree bark.
- Second photo is an unmodified  longer range laser meter designed for use by golfers (890nm). Similar rangefinders are  produced for hunters.
- Precision  xx m  Accuracy +/-1m.
- Easy to use and highly effective in all lighting over distances up to at least 100m .
- No visible light dot (890nm), accurate aiming is effected through in-built LED red dot sight.

# Laser bar caliper

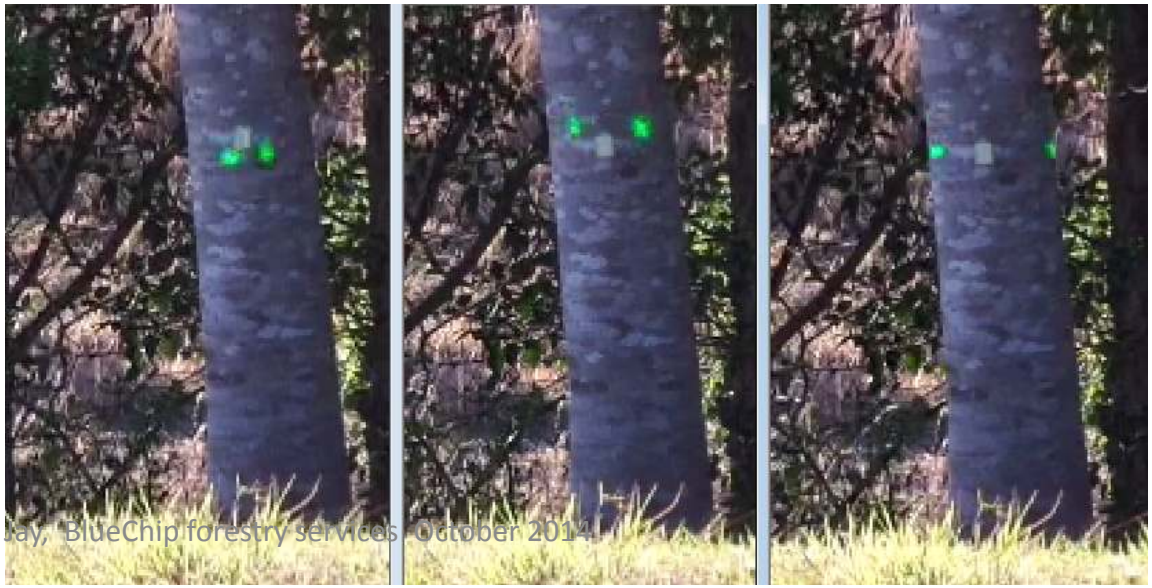
- Major advantages are ease and quickness of use, robust construction and low cost. Best suited for trees 10-100cm, distances <30m.
- Construction : Two free sliding hand pieces attached with strong magnets. 1m velcro'd steel tape and magnetic end clip. Hand pieces easily removed and slipped into backpack or belt holsters. Unpacks and assembles in just a few seconds. Galvanised rail mounts are accurate, robust and durable.
- Laser alignment is a simple procedure with plastic shims, +/-1%. Alignment must be recalibrated when laser pen is removed to change batteries.
- DBH accuracy depends on initial calibration, and then also on ability to hold steady and visually align two sighting dots to tree trunk edges.
- Major advantage of this tool is that no distance measure is needed, direct reading of DBH (max 100cm) from tape. When properly calibrated , accuracy is +/- 1cm on trees up to 50cm DBH at distances up to 20m (eg a BAF2 sweep plot). At longer distances, relative accuracy is maintained if used only on larger trees (eg BAF2, DBH>80cm at 28.3m distance, accuracy +/-2 cm).
- In the field it is often easy to improve accuracy with a few steps toward the target.

*note: for legal reasons, caliper pieces are sold separately from laser.*

1mw legal limit for pen lasers in Australia

# Laser bar caliper

- The laser caliper needs two hands while operating. In practice this means a second person or voice recorder is needed to record data. However the magnets keep the hand pieces in place so that that it can be easily held in one hand, and this permits another small device (eg BA wedge, compass, camera etc) to be used intermittently as needed.
- The photo below shows the laser dots set at 10cm, 20cm and 30cm width on a 30.5cm DBH tree at 50m distance. These are single frames excerpted from a video file. The instrument cannot be held perfectly steady, meaning the dots are dancing around noticeably on distant trees. However it is easy to place trees into say 2-5cm DBH classes depending on distance. Note the error factor associated with estimating centre of dot at distance.
- Using BAF2 sweep sampling method, a 30cm tree would not be “IN” and measured if it were more than 10.6m distant. Obtaining a reasonably accurate reading for a small tree at 50m is therefore showing that the method is robust for normal range. Critical “IN” distances for various BAF are shown later.



# Optical fork; digital caliper

- Optical fork method is based on similar triangles, and requires exact distance to tree. Range finder tools were expensive, slow and/or unwieldy until recently. Affordable portable handheld laser distance meters facilitates the use of optical fork instruments.
- Golf range finder is not precise enough (+/1m) at distances <20m. However the handheld red dot meter works well in this range.
- Digital caliper reads to 0.1mm, sighting accuracy is ~0.2mm. Held at exactly 50cm from eye by means of string. Sighting with parallax, both eyes are open. Alignment pin ensures perpendicular sighting. Small transparent teeth on device are used to aid visibility. Note caliper is also useful for measuring on camera (more later).
- Accuracy is dependent on distance and not related to tree size. eg Caliper reading +/- 0.2mm is equiv to 2cm DBH at 50m distance, or less if closer. (nb Caliper of 14.14mm is the minimum for an "IN" tree for BAF2.) Best results with this tool are when distances L<20m, although acceptable accuracy is obtained if used for large trees (>80cmDBH) at longer distance. Accuracy can often easily be improved by moving a few steps toward target.

# Monocular with scale

- Precision of optical fork methods is limited without magnification.
- Two magnifying options are 8x mini telescope with scale, or camera zoom. Instruments must be held steady while reading, which requires a tripod. DBH accuracy with monocular is 4 to 8 times better than the optical fork caliper, but using a tripod in the field is slower and more cumbersome. Sighting may be difficult in dense or dark forest.
- Can be mounted in alignment with camera and range finder on single head quick release camera tripod for best field usage and portability. Suitable for accurate upper bole measures.
- Example shows 30.5cm tree at L= 50.00m. DBH height 1.3m is just above the 7x11cm card pinned on the tree in the picture. Each scale mark is about distance L/20, or ~2.5cm (nb. calibration tests showed +2.4% correction required on this instrument)

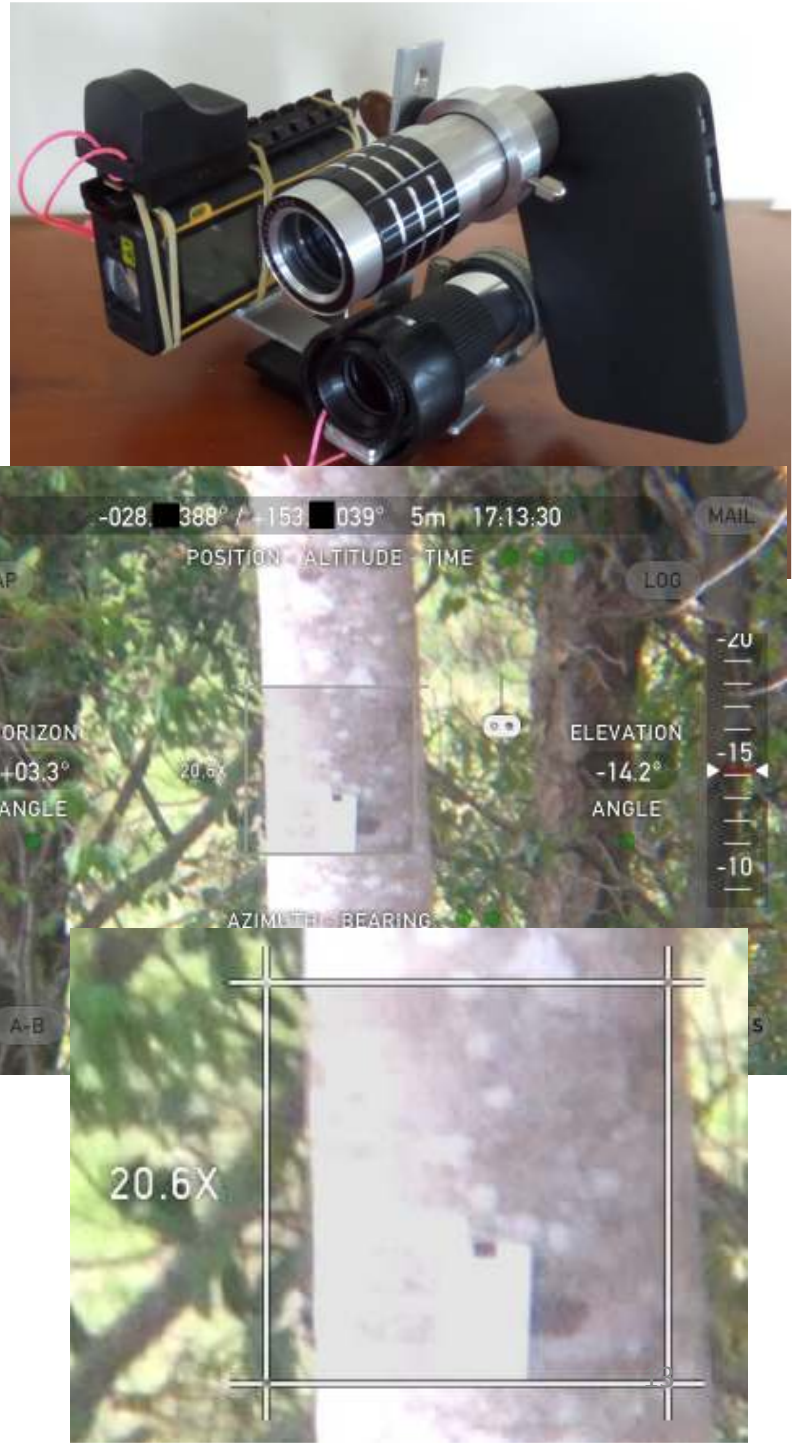
For ease of use, the instruments can be approximately aligned by manual adjustment of the bracket mounting screws. However exact alignment is not required while working.

# Camera

- Example shown is the same 30.5cm tree at 50m distance
- Photo 1 is full field of view using 14MP compact digital portable camera with 18x optical zoom. Photo 2 is an enlarged excerpt. DBH is calculated later in office from pixel count on images. → High precision measures, +/- 2 to 3 pixels, with ~1 pixel/mm at 50m distance). Photo must be centred at DBH height. Laser pen may be useful to indicate BH when photo is taken.
- Fast to use, time stamps in image metadata will facilitate data matching to GPS trail etc.
- Disadvantage is not directly knowing DBH while working. Creates possible source of data-matching error if DBH is not recorded simultaneously and directly alongside other tree data (species etc). DBH data in the field may be found by using digital calipers either (i) calibrated for measuring DBH from on-screen image replay (ref. prev.), or (ii) as optical fork. In both cases the continual tool-swapping will slow the field procedures, but result in a permanent image record and much greater DBH precision.
- Field usage hampered by bright sunlight on camera LCD display. Tripod preferred for steady shots at longer distances.

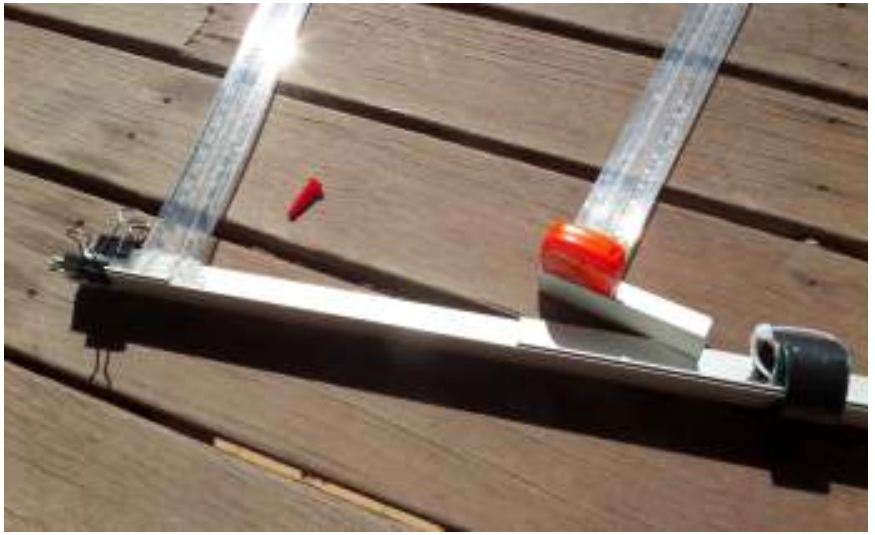
# iPhone & Theodolite app

- captures GPS co-ords, time, bearing and other info on the screen and in image file metadata.
- best when phone camera is magnified with 8x lens attachment, and high quality stable image obtained by use of tripod.
- An in-built adjustable scale on the viewing screen shows a factor which is proportional to distance. With this example tree at 50.00m, the scaling box in the centre of the photo, a first approximation for DBH,
- = 50*100/(8*20.6) =30.3cm.
- The fine control of scale factor is difficult on iPhone screen, and initial estimates are often +/-10% of DBH.
- If the box is not a close match to DBH in the image, the initial DBH guess can be rescaled accordingly, eg x110% , 80% or etc.
- Pixel count can be used later in office to refine field estimates. (caution; each phone and zoom lens combination will have minor lens differences, so must first be calibrated to obtain accuracy w.r.t pixels) .
- refer [http://hunter.pairsite.com/theodolite/](http://hunter.pairsite.com/theodolite/)



# Tree DBH Caliper

- To verify the laser bar and optical fork methods on trees, it was necessary to use a caliper rather than diameter (girth) tape.
- The simple , inexpensive and accurate tree caliper pictured here is made from two pieces of aluminium angle, held in place with a small plastic tube and two small binder clips. It is surprisingly robust and accurate in field use, and is easily disassembled for compact carrying.
- For trees up to 60cm DBH (ie using 30cm rulers) . DBH reading is made from the tape, not etched on bar.



# Tree Height


To see the top of a tree clearly it is usually necessary to stand at a distance equal to or greater than the height.

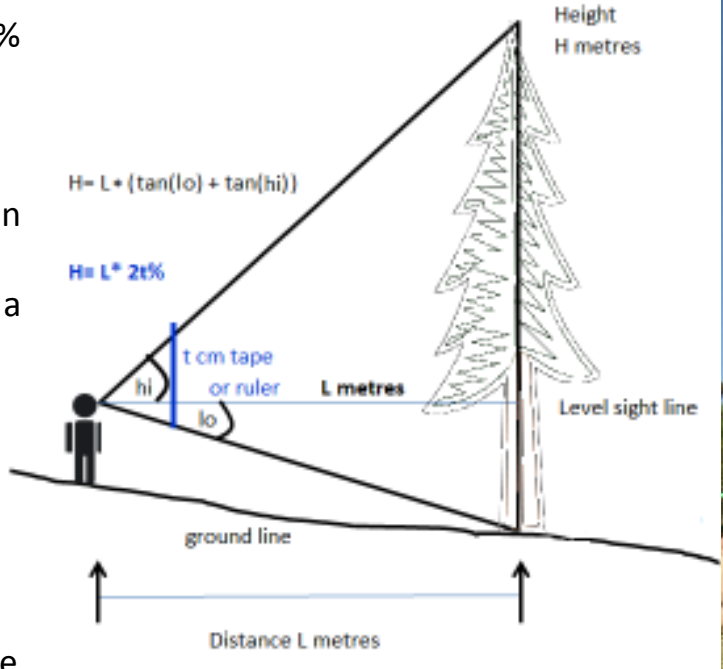
A smartphone clinometer app is a simple method to find height, requiring 2 angle measures and a known level distance to object. However its practical utility in the field depends on lighting and instrument accuracy.

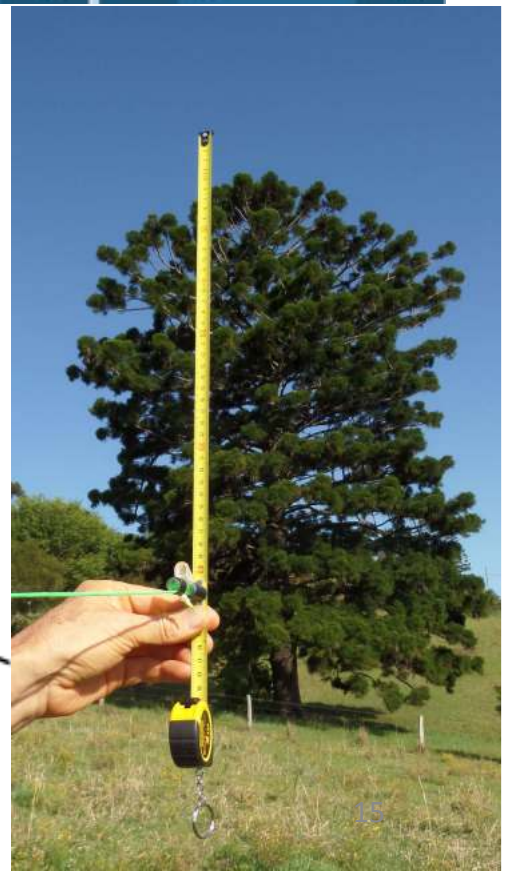
If instrument and reading errors on angles lo & hi are each +/- 1°, then accuracy of height measure is +/- 5 to 6 % of height. eg +/- 1.5m on the ~30m tree illustrated here at 40m distance.

When light is unsuitable for phone screen viewing, or better accuracy is required, an alternative low cost method is to use a ruler or tape.

For this example tree:-
Using clinometer with accuracy of +/- 1° each reading , H = 27.1m +/-1.7m

Using tape (as shown next slide) with accuracy +/- 0.5cm visual reading on tape
H= 29.6m +/- 0.4m

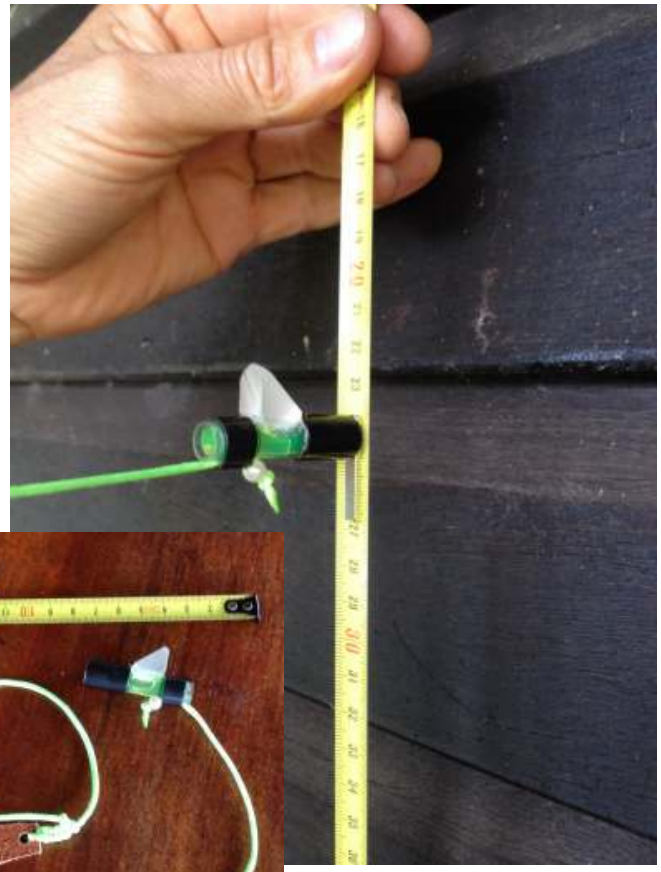


# Tree Height 2

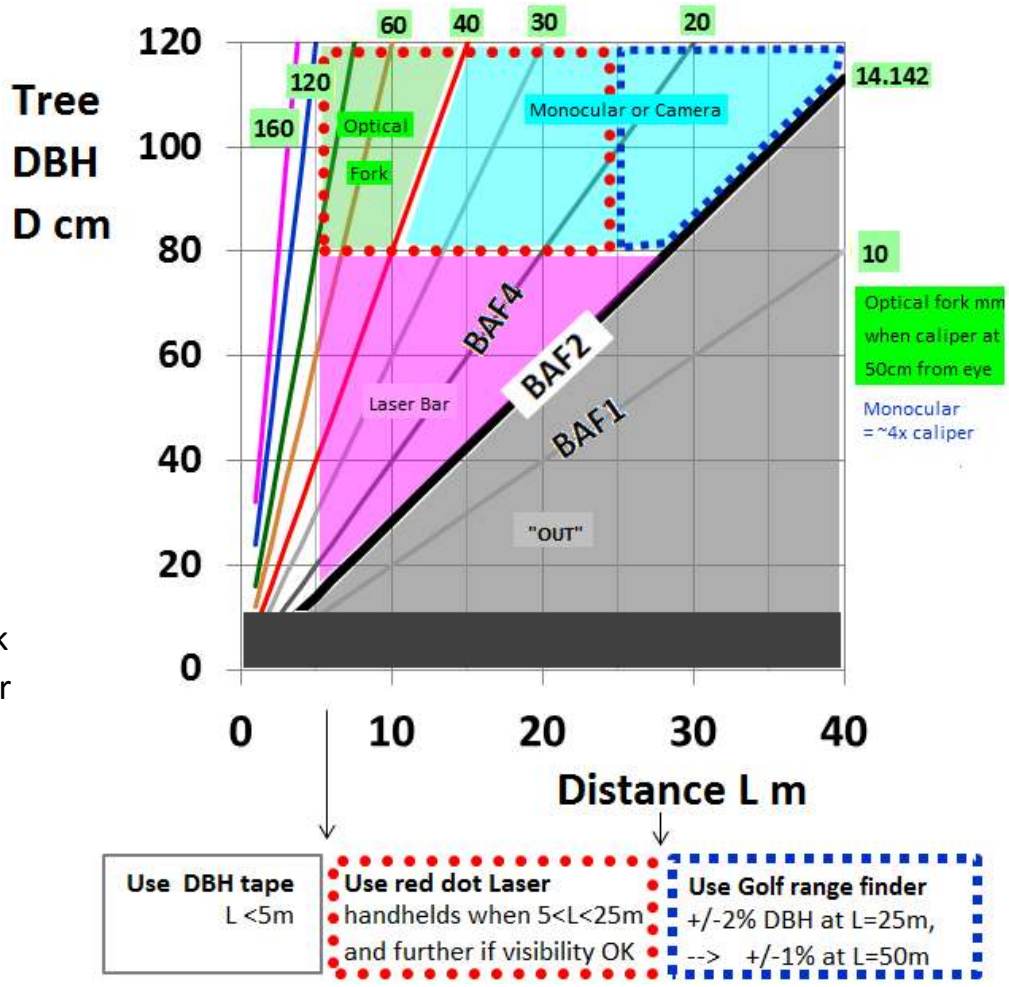
- When light is unsuitable for phone app screen viewing, a ruler held upright (plumb) at 50cm from eye is also an easy way to measure height using the principle of similar triangles. The method can be accurate if used carefully.
- The key is to be able to simultaneously hold the ruler plumb (for a non-leaning tree) and at the correct distance from eye while sighting 'through' the ruler to the base and tip of tree.
- The pictured tools use this method. A level bubble is mounted perpendicular to a metal tape, attached to the tape by magnets which allow it to slide. The level is viewed through a small 90° reflecting prism which shows when tape is plumb. This tool is very compact and robust with inexpensive easily replaceable parts.
- To measure height, the tape is locked (at any convenient length, eg 50cm ) and held vertically suspended at 50cm from the eye, with the base end of tape visually aligned to be level and in line with base of the tree. The eye to tape distance is maintained by taut string line, and the tape is made plumb by sliding the bubble level to any convenient point on the tape (eg about eye - level), and bringing it to level. The level is made by adjusting the angle of tape so as to centre the bubble which is sighted in the prism. Then tip of tree to nearest cm on tape is marked visually or by finger hold.
- With this method it also quick and easy to determine intermediate heights, eg log lengths, sedub height, crown break etc. Simplified by standing at a convenient round number distance, 20,30,40m or etc. , but any distance may be used.

**Tree Height(m) = 2 x tape cm *L/100**

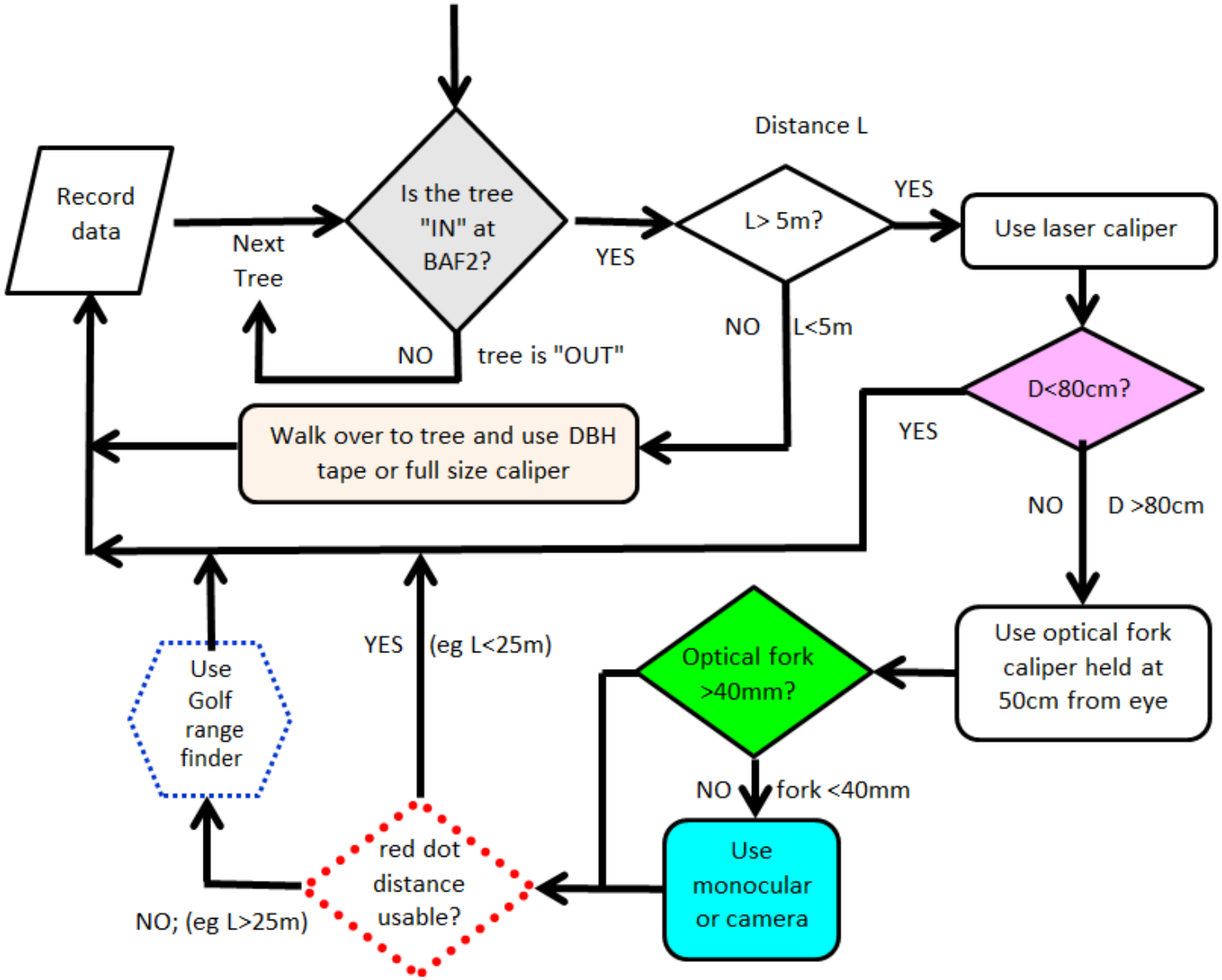


# Conclusions

- The choice of best DBH instrument depends on most commonly occurring tree sizes and plot or transect type, the forest lighting and undergrowth conditions, and purpose of measurement. The aim is to choose the instrument which offers acceptable accuracy at least cost (taking into account both field time and cost of instrument)
- The chart at right, and flow chart on next page, show suitable DBH instrument choices depending on tree size and distance.
- In most cases I would be conducting inventory by recording details for the trees "IN" a BA sweep using BAF2. The laser bar is a first preference in this case because it avoids the need to measure distance and provides a very quick and direct reading of DBH, and DBH errors do not affect BA estimates. The optical fork caliper is easily carried and used as backup for the laser bar eg for larger trees at 5-15m distance. Accuracy of the optical fork is reduced at longer distances (eg +/- 2cm DBH at 50m), but still acceptable for BAF2 sweep sampling since only large trees are "IN" at long distances.
- The monocular and/or camera method (incl Theodolite app) are slower to use in the field, and therefore only used for specific purposes where accuracy is paramount (+/-0.5cm DBH at 50m) and permanent records are required.




The laser bar is also very suited for belt transect sampling , eg all trees within 10m of a centre line.




(flow chart to be read in conjunction with chart on prev page)

For product enquiries and prices please contact

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