Forestry Commission

Assessing the stem straightness of trees

Stem straightness is important in determining tree and log value. The ability to make an effective assessment before harvesting is useful for forest managers and practitioners to improve forecasting, planning, marketing and resource use. This Technical Note describes three methods for assessing stem straightness in standing trees: visual assessment, photogrammetric measurement and terrestrial lidar. It provides basic guidance on each of the techniques and recommendations for their use. If a low cost and high speed method is required the estimates provided by visual assessment may currently be the best option. However, the visual assessment method is highly subjective and only considers a relatively small part of the saleable stem. The other two methods are computer based and directly measure the shape of stems. The photogrammetric technique described here is highly accurate but technically demanding and time-consuming, so is currently only used for research applications. Terrestrial lidar can be used for plot-based measurements and is rapidly becoming more automated, which will considerably speed up the method and could make it more attractive to users.

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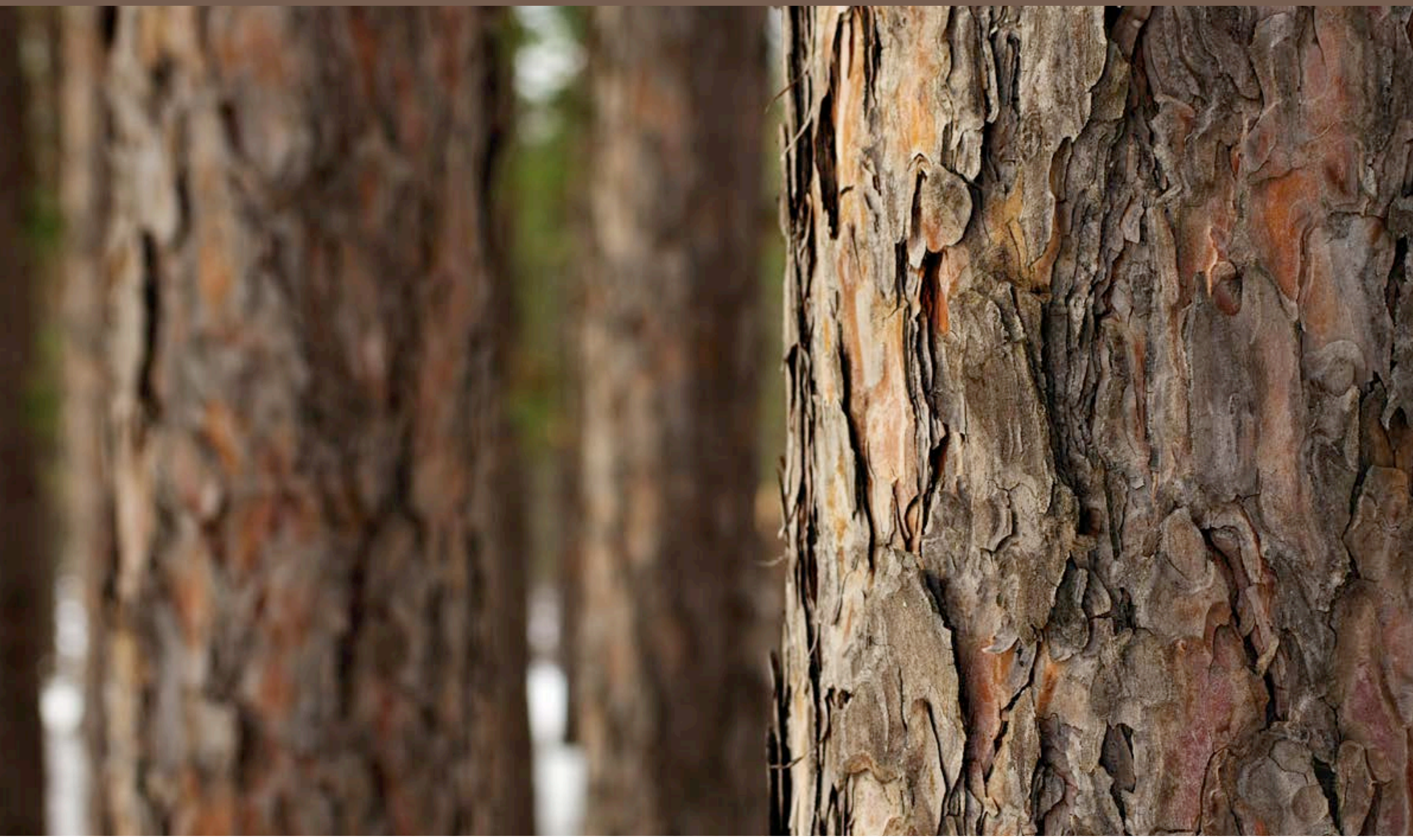
Technical Note



Forest Research

Introduction

For timber production, stem straightness is a major determinant of log value, and therefore tree value, as straight stems provide the most processing options and highest volume recovery. Effective assessment of stem straightness both at individual tree and stand level, prior to harvesting, enables managers and researchers to:

- identify better quality stands, or the better trees within stands;
- optimise resource use by identifying and marketing material according to specific processor requirements;
- reduce the incidence of rejected logs or loads;
- obtain the best prices for logs;
- include log quality information in forest inventory, production forecasting and forest planning;
- inform processors about the quality of future supplies.

Log straightness is defined according to the Forestry Commission's 1993 British softwood sawlog classification system, which requires that in straight logs the bow must not exceed 1 cm for every 1 m in length and this in one plane and one direction only. Bow is measured as the maximum deviation at any point of a straight line joining centres at each end of the log from the actual centre line of the log. This is shown diagrammatically in Figure 1.

This Technical Note describes and compares three methods that can be used to assess the straightness of standing trees in Britain:

- visual assessment
- photogrammetric measurement
- terrestrial lidar (3D laser scanning)

Visual assessment

The Forestry Commission's method for visual assessment of stem straightness was developed for Sitka spruce but can be used when assessing other commercial conifers. It may also be adapted for assessing broadleaves, where appropriate.

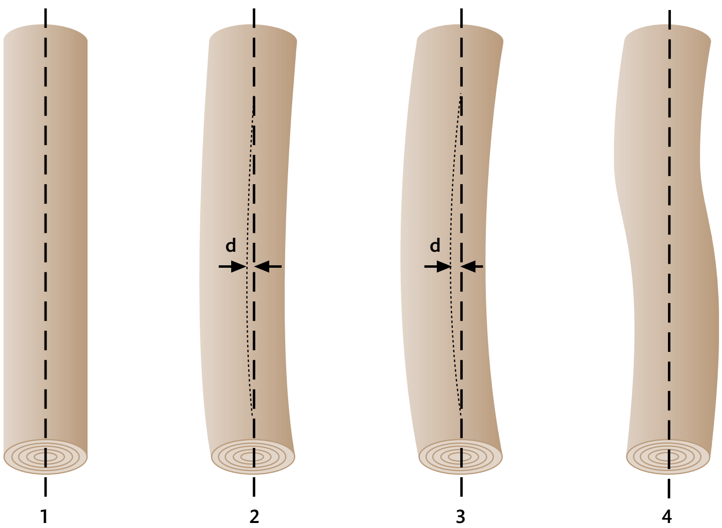
Individual tree stem straightness is based on an estimate of straight log lengths within the bottom 6 m using a scoring system from 1 (least straight) to 7 (straightest) (Figure 2).

Comparisons between stands, forests and different types of site can be made by grading overall stand quality from A (best) to E (poorest), based on the proportion of trees within each straightness score as follows:

Grade A: >40% of trees score 6 or 7
Grade B: >50% of trees score 4, 5, 6 or 7 but <40% score 6 or 7
Grade C: >35% of trees score 3, 4, 5, 6 or 7 but <50% score 4, 5, 6 or 7
Grade D: <35% of trees score 3, 4, 5, 6 or 7 but <50% score 1
Grade E: as for Grade D, but >50% of the trees score 1

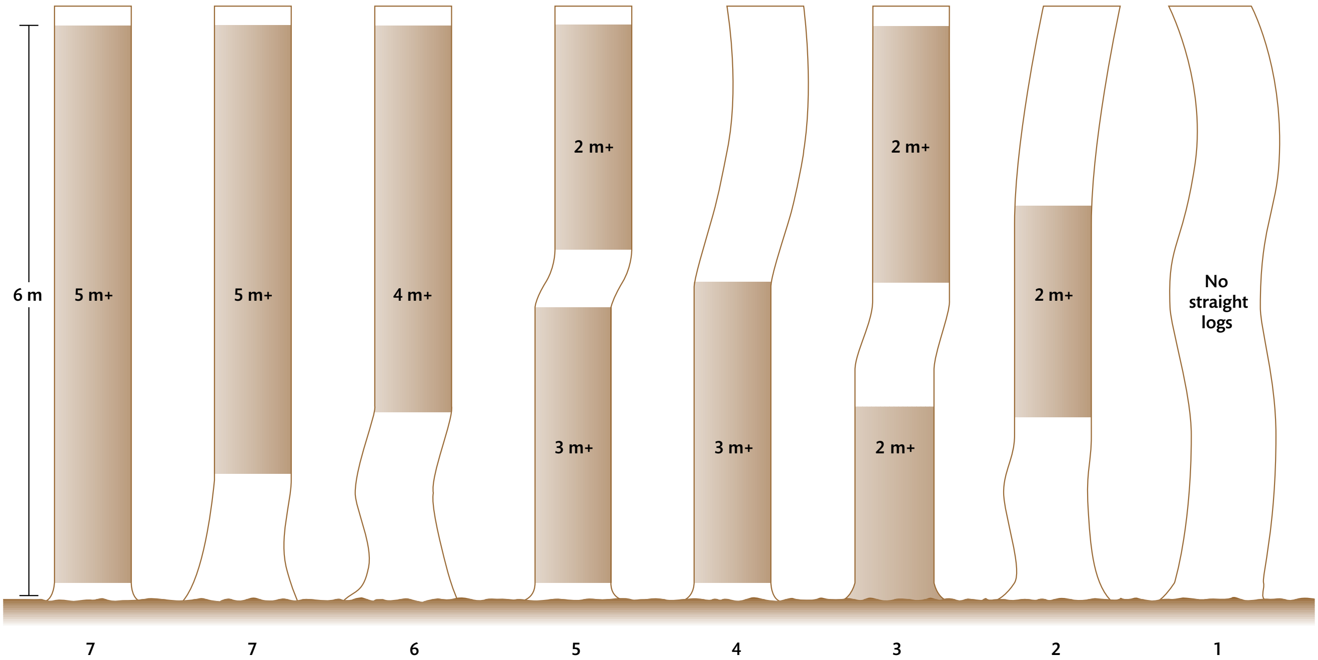
Further guidance regarding sampling intensity, minimum tree size and timing of assessments is given in the Forestry Commission Information Note *Protocol for stem straightness assessment in Sitka spruce*, which describes the technique in full. This supporting study showed that when compared with other methods such as a pole and string or hypsometer the visual method was much faster and was just as accurate, with 81% of all trees being within ±1 of the score measured after trees were felled. Of the three techniques described in this guidance, the visual method is currently the fastest by a considerable margin.

Figure 1 Examples of four logs and their straightness classifications.



- Logs 1 and 2 qualify as straight logs.
- Logs 3 and 4 are not straight.
- Maximum deviation (d) on log 2 does not exceed 1 cm over 1 m length.
- Maximum deviation (d) on log 3 exceeds 1 cm over 1 m length.
- Log 4 shows bow in more than one direction.

Figure 2 Eight possible combinations of straight log length in the bottom 6 m of a tree stem and the scores allocated to each combination. There is a reduction in quality of straightness from left to right.



It is important to remember that appropriate training, checking and refresher courses are required to ensure that this qualitative technique is applied consistently over time and between surveyors.

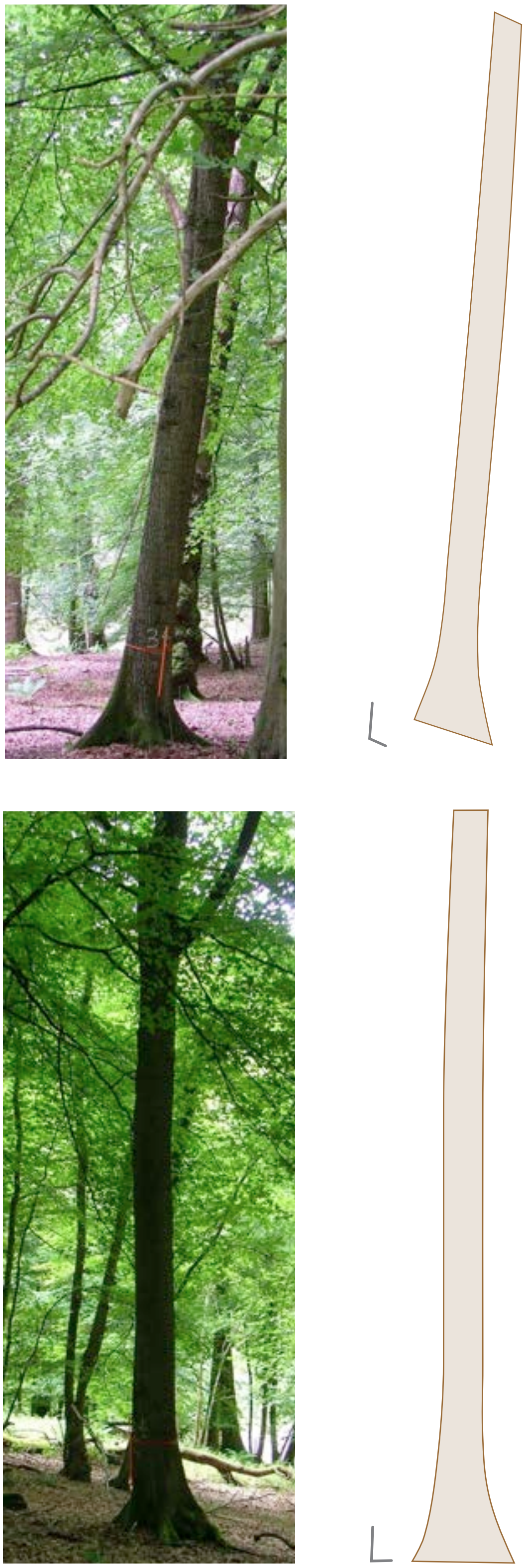
Photogrammetric measurement

The photogrammetric measurement method measures the straightness of the lower 10 to 12 m of the stem via analysis of a three-dimensional (3D) profile of any standing tree. Two digital photographs of the standing tree, perpendicular to each other (Figure 3), are taken using a camera mounted on a level tripod. A plumb line is attached to the tree stem to indicate the true vertical, alongside a brightly coloured rod, 1 m in length, so that the spatial dimensions of the image can be calibrated. The method is limited by the availability of two clear (i.e. line of sight) and stationary perpendicular views and could therefore be affected by live crown density or windy conditions.

Figure 3 Examples of photographs of three different trees taken for 3D profiling (note the 1 m rods used for scaling; the plumb lines are not visible).

Image analysis software is used to determine the diameter and centre point of the stem in both 2D planes, which can then be combined to generate a 3D reconstruction (Figure 4). Stem straightness is determined from the 3D reconstruction by geometrical calculation of the principal axis of the tree and from the deviation of centre points of the stem from it. The method can measure stem diameter and orientation to within 7 mm using a 3 mega-pixel camera. In addition to the simple stem straightness classification, more detailed information on stem form such as the angle of lean, stem sinuosity and lean orientation can be obtained.

Figure 4 3D stem reconstruction from two orthogonal photographs of the same tree (note that the original photographs do not need to be of particularly high quality in terms of colour, brightness or contrast).



Terrestrial lidar (3D laser scanning)

Lidar (light detection and ranging) uses lasers to measure the distance between a sensor and an object. It is similar in principle to how the more widely known radar (radio detection and ranging) uses radio waves. Laser beams can be highly focused and consequently they can be used for applications that require a high spatial resolution, such as surveying. Lidar can be used via terrestrial, airborne or satellite platforms in a variety of applications, and while lidar from all of these platforms has been applied to forestry, currently only terrestrial lidar (Figure 5) offers the possibility of acquiring high-resolution data relating to the 3D stem form and straightness. Early terrestrial laser scanners were expensive, bulky and heavy, which limited their practicality in remote, steep or rough terrain. However, costs, size and weight are all reducing very rapidly as new technologies become available, and their application in forestry is growing.

The raw output from terrestrial laser scanners, the name commonly given to terrestrial lidar platforms, consists of a series of 3D co-ordinates known as 'point clouds'. To extract the desired information, point clouds are processed in computer software. The majority of commercially available software is designed for surveying (e.g. architectural, engineering, cartographic) purposes and most software relating to forestry applications is still in the research and development

Figure 5 Operating principle of a terrestrial laser scanner.

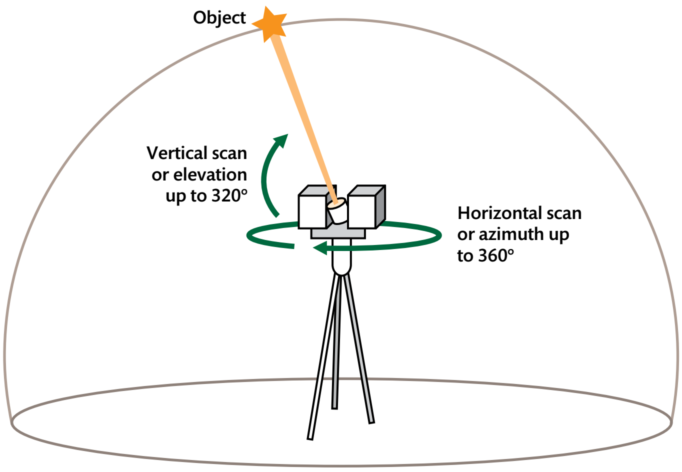
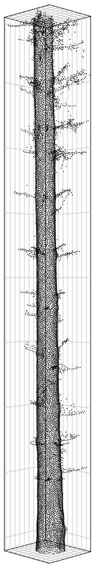


Figure 6 Setting up a tripod mounted terrestrial laser scanner (left) and the point cloud of a scanned tree (right). The spheres placed around the tree are used to both position and superimpose scans from multiple points of view.



stage. The basis of the technique used to derive information about stem form from point clouds is to geometrically fit a sequence of cylinders joined tip to tail, which allow the determination of taper and straightness. These processes are time-consuming if performed manually, therefore algorithms have been developed and are currently being continually refined to detect trees and filter the point clouds in order to use this approach in forest stands.

Comparison of the techniques

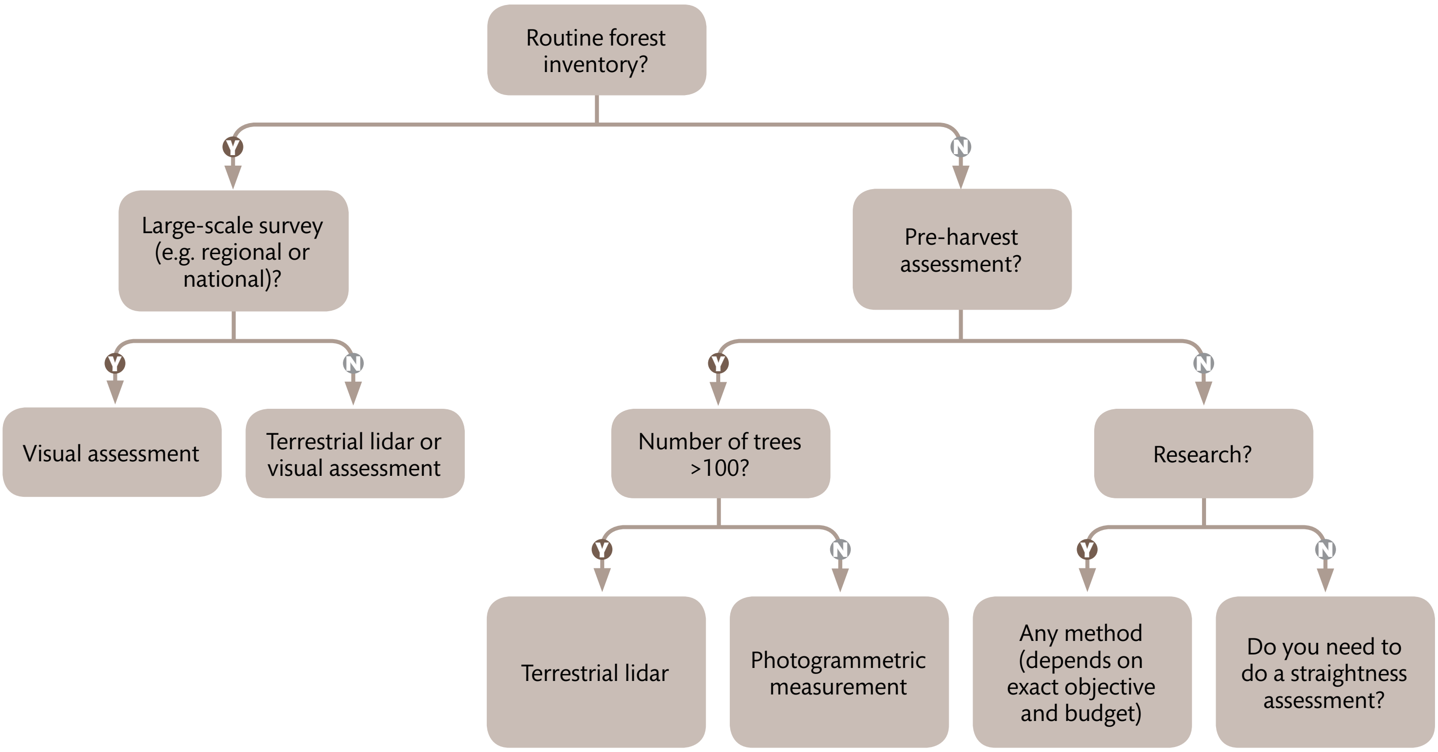
The three techniques and their applications, advantages, disadvantages and recommended uses are summarised in Table 1, while Figure 7 provides a decision tree for selecting the most appropriate method for a particular situation based on the current state of the art. The chosen method should take account of the exact objectives of the user, cost in relation to potential benefit and operator experience.

Table 1 Summary of applications, advantages, disadvantages and recommended uses of the three techniques.

Method	Tools	Time (current estimates)	Applications	Advantages	Disadvantages	Limitations	Recommended uses
• Visual assessment	• Straight edge	• Less than five minutes per tree	• Forest and wood quality research • Forest inventory	• Fast • Cost effective	• Qualitative • Lower accuracy • In trials, operators tended to underestimate straightness in better logs	• Subjective	• Routine forest inventories
• Photo-grammetric measurement	• Digital camera • Tripod • Coloured metre stick and plumb line • Computer with image analysis software	• Up to 20 minutes per tree for image capture (field time) • Up to 10 minutes per tree for image processing (office time)	• Forest, wood quality and tree physiology research • Inventory of high value stems	• Quantitative • Very accurate • High precision • Relatively cost effective	• Time-consuming	• Low light conditions • Wind • Heavy branching and other viewpoint obstructions • Technical competence	• Forest research • High value trees
• Tripod based terrestrial lidar	• Laser scanner (plus tripod and position targets) • Computer with processing software	• 40 minutes per plot (field time)[1] • Point cloud processing (office time)[2]	• Forest, wood quality and tree physiology research • Forest inventory	• Quantitative • Relatively fast • Accurate • High precision • True 3D	• Relatively expensive (equipment cost and skilled operator time) • Relatively bulkier and heavier equipment (but smaller machines appearing)	• Better suited to lower density stands • Heavy branching and other viewpoint obstructions • Weather (windiness, precipitation) • Technical competence	• Pre-harvest assessment • High value trees • Long-term monitoring • Research

1 This includes set-up and making four scans per plot at low resolution using an experienced operator.
2 No accurate estimate is available as no standard approach exists; however, it is possible to examine the dimensions of trees manually using standard surveying software in which case a similar processing time to the photogrammetric method can be expected.

Figure 7 Decision tree for selecting the most appropriate methodology based on currently available technology.



The visual assessment method currently offers the simplest and fastest way of sampling and assessing stem straightness at stand level. The technique is both subjective and of lower accuracy, but it represents a cost-effective solution for routine forest inventories as long as experienced assessors are available. The photogrammetric measurement technique described here provides accurate pseudo-3D profile measurements, but is also the most technically demanding. Because of the time required for assessment and processing of data the method is likely to remain limited to research applications unless the automated image-processing procedure can be further developed. Terrestrial laser scanners have considerable potential for further development and use in the assessment of tree and stand architecture, but some method development is still required.

Useful sources of information

Forestry Commission publications

- Classification and presentation of softwood sawlogs. Field Book.
- Protocol for stem straightness assessment in Sitka spruce. Information Note.

Journal articles and other literature

- The use of terrestrial lidar technology in forest science: application fields, benefits and challenges. (Annals of Forest Science).

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FCTN021/FC-GB(JW)/WWW/JUL17

ISBN: 978-0-85538-958-1