# Chapter B5 – YIELD ESTIMATION

## Standard for Yield Estimation

**Purpose**

The purpose of this standard is to ensure:

- a description and disclosure of the basis for all estimates of the quantity and quality of current and future yield in the forest covered by the forest description; and
- conformity of yield estimation with the overall forest description, including forest area, stand history, costs and log prices.

Consideration of yields is required irrespective of the valuation approach.

**STANDARD B5.1**
**Yield estimation**

**The forest description shall:**

- **describe the base measurement data underpinning the yield tables, including:**
  - **a declaration of the area for which base measurement data: (a) comes from an inventory; (b) does not come from an inventory**
  - **where base measurement data comes from an inventory:**
    - **population age at time of measurement**
    - **sampling design and intensity**
    - **inventory procedures and execution**
    - **elapsed time since measurement**
    - **rules used to associate inventory populations with forest description area units**
    - **steps taken to verify that the inventory data is representative of the forest description land units to which it is applied.**
  - **where base measurement data does not come from inventory data:**
    - **where it does come from;**
- **describe the modelling process that generated the yield tables from the base measurement data, including:**
  - **the models and assumptions used**
  - **rules used to select from amongst alternate models and inputs for forest description area units**
  - **references to supporting reports that justify the choices of models and their performance, with particular reference to the valuation context;**

- **describe the steps taken to ensure consistency of yield estimates with other components of the forest description, including forest area, stand history, costs and log prices; and**
- **provide the results of comparative analyses that inform about the quality of yield estimates and any adjustments applied as a consequence. Examples of comparative analyses include:**
    - **comparison with independent inventory**
    - **comparison with historic production data**
    - **comparison with reasonable expectations**
    - **comparison with yield tables used in previous valuations of the same estate**
    - **comparison of generic with subsequent specific yield tables**
    - **audit by re-measurement of a sample of recent inventory plots.**

## Guidance Notes on Reporting Yield Estimation

**Background**

This section is about the development of **base** yield estimates as opposed to the aggregated yield tables that might be presented to a forest estate model. Aggregation of **base** yield estimates to reduce the forest description to a manageable size is covered further in Chapter 4.

A yield estimate is an estimate of the availability of one or more products at some specified point in time.[1] In the commonest cases this means an estimate of the volume per unit area of each of a number of merchantable log grades at a point in time at or after the valuation date. It is common practice to prepare estimates for the same area at multiple future points in time, with each point representing a feasible time of harvest (i.e. a yield table). It is also common practice to define the points in time using an offset from the time of planting (age) instead of using calendar time.

In a forest description suitable for valuation, each identifiable area (polygon or stand) that is considered to be productive will be associated with a yield table for the current crop and be treated as uniform with respect to yield. It may also have a yield table for future crops if the valuation spans multiple rotations. Multiple areas may share the same yield table.

In a forest description suitable for forest planning, each identifiable area may have multiple yield tables representing different management options (e.g. thinning options) or mixes of products.

Underlying most yield estimates are two key components:

1. Measurements of trees at a point in time.
2. Models that convert the tree measurements into yield estimates at future points in time.

It is common for tree measurements to represent a sample within a pre-defined boundary, collected to estimate the yield within that boundary (i.e. forest inventory within a pre-defined inventory population).

**Models**

Models include, without limitation:

1. Imputation models to fill in unmeasured values (e.g. diameter/height regressions)
2. Statistical models (estimators) that incorporate auxiliary information such as remote sensing data with the tree measurements.
3. Growth models, including height models and mortality functions.

[1] Stand parameters, such as total recoverable volume and piece size, may be associated with product yield estimates and may, through their use in harvest cost models, have a direct bearing on the valuation.

4. Thinning selection models for thinning events that occur after measurement.
5. Taper and volume functions.
6. Breakage functions.
7. Log-making algorithms and associated log grade specifications.
8. Other product allocation models.
9. Wood quality models (e.g. basic density or pruned log index).
10. Conversions between units of measure (e.g. cubic metres to tonnes).
11. Adjustments to represent loss-in-process, including volume loss and/or value loss (downgrade).
12. Adjustments for losses due to natural events such as fire or wind.
13. Adjustments to allow for anticipated future changes (e.g. genetic gains or climate change).

Models include adjustments made by the valuer.

Some of these modelling steps can be handled in more than one place. For example, the tendency for some proportion of saw logs to be sold as pulp logs can be modelled as a reduction in saw log volume in the yield tables. A more transparent approach is to reduce the realised price of saw logs without reducing their volume. It is incumbent upon the valuer to ensure that they understand how this phenomenon is handled and that it is not handled twice.

It is convenient before aggregation to consider the process of generating yield estimates as applying to the smallest unit of land area in a forest description process. The key decisions for such a unit are:

1. What tree measurements to use.
2. What models to use.

It is important that the forest description documentation describes the decision processes that answer these questions.

**Additional Concerns**

Additional concerns for a user of a forest valuation that need to be addressed in the documentation can be broadly grouped into these areas:

1. Representativeness.
2. Model choice and performance.
3. Consistency.

**Representativeness**

Assuming that tree measurement data has been collected for the forest within pre-defined areas (inventory area) using a design or probability-based approach to sampling, then the following cases may occur:

1. The inventory area is the same as the forest description land unit and the tree measurements are fully ‘representative’ of that land unit. This is a good situation to have, but often only applies to older stands in a forest, woodlots and small stumpage sales.
2. The forest description land unit is a subset of an inventory area. The inventory area is ‘representative’ of a larger area than a single stand or polygon. Using a good average across multiple stands or polygons is good practice, but raises concerns in a valuation context in some specific cases:
    a. the valuation applies to a subset of the whole inventory area, with the subset possibly differing in an unknown way from the average (e.g. a single stand with a yield table based on the sampling of an entire age class); or
    b. a non-random subset of the inventory area has been removed since measurement. The inventory was once an unbiased sample for all of a large area but, for example, the best parts have already been harvested and replanted.
3. There are no forest inventories that apply directly to the forest description land unit, or a superset that contains it, and tree measurements have instead been chosen from inventories that represent other parts of the forest (or even other forests). This is often best practice when applied to stands that have not reached an age where measurement makes sense (i.e. before the available models produce good estimates and for the unplanted crops of future rotations). However, the following concerns can arise and should be noted where they occur:
    a. where the existing inventory is not ‘representative’ of the unmeasured areas (e.g. when failed stands are not measured because there is no intention to manage them, but they instead receive the average for normal stands);
    b. when the future is not the same as the past (e.g. when site productivity or silviculture are different in unmeasured stands); and
    c. when selection from existing data is likely to produce a biased estimate for unmeasured areas because it makes inappropriate use of area weighting and/or fails to recognise auxiliary variables that are correlated with yield (e.g. altitude).

The outcomes of cases 1 and 2 are often referred to as ‘specific’ inventory or ‘specific’ start points because the tree measurements are specific to identifiable areas. The outcome of case 3 is often called a ‘generic’ start point to distinguish it from the ‘specific’ cases. It is good practice in documenting a forest description to provide a summary of the area by age to which the specific and generic cases apply.

**Appropriateness of model choice**

It is rarely possible in a valuation context to check that a model component (e.g. taper function) is correct. There is little pragmatic alternative but to turn to documentation from existing studies that justify a modelling approach and choice of model components.

It is good practice to document the decisions that are used to choose between alternative models for each forest description land unit.

It is good practice to document the modelling approach, to critically appraise reports of the studies that support or refute the approach and the choice of model components, and to cite these in forest description documentation.

**Consistency**

Forest description is a minefield for consistency issues. It is not possible to provide an exhaustive list because these factors depend on the source of measurement data and the modelling approach. The following are likely to occur in the context of yield estimation if insufficient attention is applied:

- yield estimates using different units of measure to prices (e.g. $/m$^3$ c.f. $/tonne);
- prices based on different standards of value recovery than recognised in modelling (e.g. the 'optimal' grade mix versus market uptake);
- yield estimates calculated for Net Stocked Area (NSA) that are applied to the total area;
- timing conventions that differ between the yield tables and the cashflow discounting convention. When yield tables are provided in one-year steps, which is common practice, then there is only one point in any calendar year when the yield estimates are correct and that point may not coincide with the point in the year when cashflows are assumed to arise;
- inconsistency between the assumptions used to build a calibration model and the assumptions used to apply that model (e.g. an implied discount rate model); and
- inconsistency between assumptions about the effect that future silvicultural events will have on yields and on future costs (e.g. estimating pruned volume without recognising the cost of pruning).

One important role of forest description documentation is to assure the reader that these and other consistency issues have been appropriately addressed. The process of documenting how they have been addressed is an important step in ensuring that they have actually been addressed.

**Comparative Analysis**

In cases where the valuation does rely on the magnitude of the predicted future cashflows, it is good practice to provide the results of comparative analyses that provide information about the quality of the yield estimates.

These can include:

- comparison with independent inventory. At a sample of locations (plots) forest valuation yield estimates are compared with new estimates from new tree measurements. This approach provides information about potential bias in the forest inventory that underpins the yield estimates in the valuation. It does not validate the choice or performance of models. Because the new measurements are costly, this approach is only warranted in some cases;
- comparison with historic production data. This is primarily useful for assessing value recovery assumptions because recently harvested areas tend to have very good inventory data that was updated just prior to harvesting;
- comparison with reasonable expectations. These reasonable expectations can be based, for example, on:
  - experience with the productivity of similar forests
  - national production figures and/or site productivity surfaces
  - mathematics (e.g. trees have well-known shapes that set an upper limit on the proportion of pruned volume for known pruned height and tree height);
- comparison with yield tables used in previous valuations of the same estate;
- comparison of inventory process with industry best practice;
- re-measurement of a subset of recent inventory plots. It should be noted that this can only provide information about recent measurements; and
- comparison of yield tables within the same description:
  - generic versus specific
  - young versus old stands.

It is not enough to compare. The valuer must also interpret results in order to inform about the quality of yield estimates and any adjustments applied as a consequence.

## Revision History

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| **Original Standard** | Released in May 1999 |
| **Revision in August 2020** | Main changes are:<br>• focusing the standard on: (a) describing the base measurement data; and (b) describing the modelling process used to generate yield tables from the base measurement data;<br>• requiring a description of all models and assumptions used, rather than requiring them only for specified models and assumptions;<br>• requiring a description of the steps taken to ensure consistency of yield estimates with other components of the forest description; and<br>• requiring the results of comparative analyses that inform about the quality of yield estimates. |