
# A Pre-harvest Timber Valuation System

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- **Prior to the purchase and harvest of a stand of timber, sawmills require information regarding the volume, the number and the size classes of different log types that can potentially be cut from the stand.**

- **The purpose of this COFORD funded project was to develop a decision support system (DSS), incorporating pre-harvest measurement and analysis procedures, to provide the timber procurement manager of a sawmill with estimates of the volume, number and diameter class breakdown of log assortments that can potentially be cut from standing timber lots.**

- **The system was evaluated using nine data sets, including seven Sitka spruce (*Picea sitchensis* (Bong.) Carr.) clearfells, a Sitka spruce thinning and a Norway spruce (*Picea abies* (L.) Karsten) clearfell.**

- **An interactive computer program was developed which employs a generic taper equation and site-specific dbh/height model to profile the stems. Using log specifications supplied by the user, the program then simulates cut-to-length harvesting and produces forecast estimates of yield for each log-type, in terms of the volume and number of logs in each of a series of small-end diameter categories.**

- **The DSS provides the sawmill manager with an efficient means of gaining a comprehensive insight into the yield potential of standing timber lots and represents a valuable aid to timber procurement and production planning.**

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Sawmills require specific information on the volume, the number and the diameter classes of different types of log assortments that could potentially be cut from a stand which the mill intends to tender for or harvest. Knowledge of the consequences of adopting a particular cross-cutting strategy would also enable mills to identify the optimum combination of products to be harvested from a stand, subject to operational constraints and the need to satisfy customer demands for sawn timber. With a greater insight into the yield potential of a crop in terms of actual products, tender prices could also more accurately reflect the value of individual stands to different mills. Accordingly, a pre-harvest measurement and analysis procedure has been developed. The inventory procedure was designed to enable the timber procurement manager to acquire, at reasonable expense, information that, when analysed, provides a comprehensive insight into the yield potential of the stand.

## Objectives of the Study

The objectives of the study were (Nieuwenhuis and Malone, 1999):

- Design an efficient inventory procedure (including a dbh/height model) to collect data on the dimensional properties of a standing timber lot prior to sale or harvesting (Malone 1998);
- Develop a generic taper-estimating system to accurately predict stem diameters, applicable to stands harvested by Palfab Ltd. (Malone 1998; McHugh 1999);
- Develop a computer program that employs stand specific inventory data and the generic taper equation to forecast the yield and dimensions of potential log products from a stand, to which meaningful values can be assigned (Malone 1998; McHugh 1999);
- Evaluate the developed system, using data from a variety of stands (McHugh 1999; Nieuwenhuis et al. 2001).

The outcome was an integrated decision-support system (DSS) which enables management to examine the consequences, in terms of the volume, number, sizes and value of products, of adopting alternative approaches to harvesting individual stands. Information of this kind allows for the most appropriate approach, given market demands and production constraints, to be identified and adopted.

This research project was undertaken in conjunction with Palfab Ltd., a medium-sized softwood sawmill which purchases over 90% of the logs it processes from standing sales.

**Data**

The tree section data consist of 9,696 observations of diameter and height made on 412 stems, from nine stands (see Table 1). The standing timber lots, selected by Palfab, were considered to be representative, with respect to mean dbh, mean tree volume and location, of those normally purchased by the mill. An identical data collection procedure was followed in each stand. The diameter overbark at breast height was measured with the aid of an electronic calliper. The point at which this measurement was taken was marked on the standing tree so as to provide a means of determining stump height. The trees were subsequently felled and measurements were taken (in mm) at 0.5 m intervals to a distance of 6.0 m from the butt and at 1.0 m intervals thereafter to an approximate top diameter of 70 mm. In addition, the lengths, to the nearest centimetre, from the butt to the breast height mark and to the tip were also recorded.

Seven of these data sets (i.e. 1, 2, 4, 6, 7, 8 and 9) were used in the validation phase. Four of these data sets (i.e. 6, 7, 8 and 9) were used for the testing of the developed inventory procedure over a wider range of stand types as that used during the development phase (McHugh, 1999). The sites included two Sitka spruce (SS) clearfells (SS/CF), a SS thinning (SS/TH) and a Norway spruce (NS) clearfell (NS/CF). As these data were not used for development purposes, all observations were used in the evaluation.

**Taper equations**

An extensive review of the forestry literature was undertaken with the aim of identifying suitable taper equations. (A preferred taper equation should provide an unbiased estimate with minimum variance of stem diameter at any given distance from the butt, total stem volume and individual log volumes.) The eight models that were retained following the preliminary assessments were employed to generate estimates of stem diameter corresponding to the measurements actually taken on the stems. The actual total volume and the estimated volume to tip of each validation tree were calculated in sections with Smalian's formula. In addition to the traditional predictions of stem diameter and total volume, the performance of the models in predicting log volumes was also tested. The estimated log volume content of each validation data set was calculated using each of the eight candidate taper equations.

**Dbh/height models**

After an initial assessment, three models that produced estimates of tree height with the least bias and minimum standard error were subjected to a more judicious evaluation. An investigation was undertaken to determine the performance of the three diameter-height models when applied to height-sample trees obtained by means of two different sampling schemes (i.e. simple random and stratified) and, for each scheme, three different sample sizes (i.e. 5, 10 and 15). A unique diameter-height curve was developed for each stand. The performance of each of the eighteen combinations was then assessed for predicting tree height and for estimating stem diameter and total stem volume also.
A computer program was developed with the Visual Basic for Applications (VBA) programming language to simulate the process by which sawlog, palletwood and

***Table 1: Summary characteristics of the stands used in the study.***

| Stand | Forest | Planting Year | Yield Class ($m^3$ $ha^{-1}$ $an^{-1}$) | Mean dbh (cm) | Species and Harvest Type | Number of Sample Trees |
|---|---|---|---|---|---|---|
| 1 | Skibbereen | 1958 | 24 | 27 | SS/CF | 54 |
| 2 | Kenmare | 1954 | 18 | 26 | SS/CF | 64 |
| 3 | Killavullen | 1956 | 18 | 23 | SS/CF | 38 |
| 4 | Inchigeelagh | 1956 | 22 | 32 | SS/CF | 59 |
| 5 | Inchigeelagh | 1956 | 22 | 30 | SS/CF | 31 |
| 6 | Kenmare | 1958 | 18 | 24 | SS/CF | 38 |
| 7 | Bandon | 1953 | 20 | 27 | NS/CF | 48 |
| 8 | Ballingeary | 1952 | 16 | 29 | SS/CF | 33 |
| 9 | Dunmanway | 1958 | 20 | 24 | SS/TH | 47 |

Source: Coillte Teoranta *Note: SS = Sitka spruce, NS = Norway spruce, CF = clearfell, TH = thinning.*

*Table 2: Average sawlog volume ($m^3$/log) for the validation data sets, as estimated by the simulator and as calculated by the optimal cross-cutting procedure.*

| Stand | Forest | Species/ Harvest type | Number of trees | Simulated Volume ($m^3$/log) | Optimal Volume ($m^3$/log) | Percent difference |
|---|---|---|---|---|---|---|
| 1 | Skibbereen | SS/CF | 19 | 0.317 | 0.291 | -8.93 |
| 2 | Kenmare | SS/CF | 21 | 0.246 | 0.219 | -12.33 |
| 4 | Inchigeelagh | SS/CF | 19 | 0.296 | 0.281 | -5.34 |
| 6 | Kenmare | SS/CF | 38 | 0.267 | 0.271 | +1.48 |
| 7 | Bandon | NS/CF | 48 | 0.304 | 0.302 | -0.66 |
| 8 | Ballingeary | SS/CF | 33 | 0.321 | 0.316 | -1.58 |
| 9 | Dunmanway | SS/TH | 47 | 0.212 | 0.221 | +4.07 |

*Note: SS = Sitka spruce, NS = Norway spruce, CF = clearfell, TH = thinning.*

pulpwood are cut from the stem. The program thus determines the number of logs and the total volume of each log type that could be cut from the stem so as to maximise cut-to-length value. The program requires from the user:

1. Inventory data in the form of a dbh value for each sample tree and values of both dbh and height for each height sample tree;
2. A prioritised list of up to 12 log types, specifying, for each, its length and minimum small-end diameter (sed) and the corresponding value per cubic metre;
3. An estimate of average stump height for the stand.

The results generated for each analysis include:

- The total volume of each log type;
- The total value of each log type;
- The total number of pieces of each log type;
- The mean volume of each log type;
- The number of pieces of each log type that lie in each sed category;
- The volume of each log type that lies in each sed category. Given an appropriate sampling scheme and an estimate of the total number of stems in the stand, the above results can be extrapolated to the entire population.

To obtain an overview of the accuracy of the results produced by the developed inventory procedure, data from a wide range of stands were processed by both the inventory procedure and by an optimal cross-cutting program which uses a dynamic programming algorithm (Nieuwenhuis, 1989). As this program uses detailed stem measurements and an optimisation procedure, the results produced by this process are assumed to be optimal. The results of the developed DSS were evaluated against these optimal results. The output frequency tables produced by the DSS and the optimiser (OPT) were compared in detail. First of all, the breakdown of total volume into the different assortments was examined on a cubic metre and on a percentage basis. Similarly, the breakdown of the total log count into the numbers of logs in each of the assortment categories was analysed. This gave a clear indication of the capacity of the DSS to determine overall assortment estimates. The next step was to evaluate the breakdown of the sawlog assortment volumes and log counts into the small end diameter (sed) categories.

## Results

### Taper equations

When the initial performance rankings for diameter and total stem volume were combined with those for the log-product volumes, the 8-variable Kozak model (Kozak 1988) was found to exhibit the least overall bias and standard error. This equation performed consistently well, producing accurate estimates for all five selection criteria, and produced no unusual predictions. For these reasons, the Kozak '92 (8) model was selected for incorporation into the cross-cutting simulation program, and for use in evaluating alternative inventory procedures.

### Inventory procedure

Overall performance ranking based upon values of bias and standard error of estimate (SEE) for tree height, diameter and total stem volume associated with each of the eighteen combinations of sampling technique, sample size and dbh/height model were analysed. The Curtis dbh/height model (Curtis 1967), in combination with simple random sampling and a sample size of ten, was chosen to form the basis of the inventory procedure.

### System validation

The average sawlog volumes for the validation data sets, as produced by the two procedures, are presented in Table 2. It can be seen that all estimates from the DSS for stands 1, 2 and 4 were higher than the actual values as produced by the optimiser. This is the result of an over-estimation of the volumes, based on data sets that were too small to produce accurate estimates. The estimated numbers of sawlog were however very close to the actual values. The average sawlog volumes as estimated by the DSS for clearfell stands 6, 7, and 8 were all very accurate (within 2% of the real values), while the DSS estimate for the thinning operation in stand 9 was within 4% of the OPT value.

Examples of sawlog frequency tables for two data sets are presented in Figures 1 and 2 . Overall there was a very close similarity between the estimates produced by the DSS and the optimal values produced using the detailed stem measurement data. The accuracy of the estimates for the Dunmanway thinning site (Figure 2) was remarkable, as this stand was outside of the range of stand types on which the system was based.

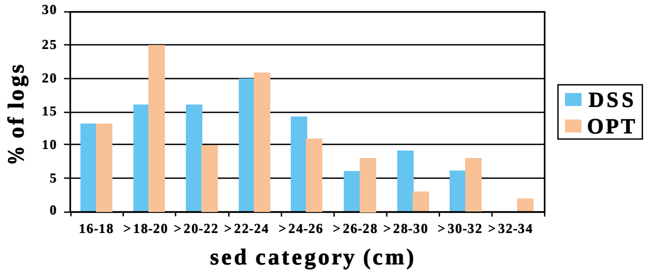


***Figure 1. Sawlog frequency distribution (in percent of number of logs) by small end diameter category for Ballingeary (Sitka spruce clearfell).***

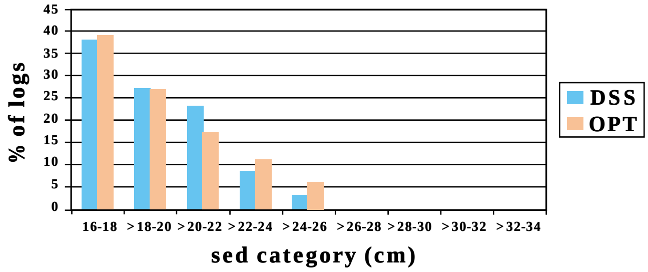


***Figure 2. Sawlog frequency distribution (in percent of number of logs) by small end diameter category for Dunmanway (Sitka spruce thinning).***

## Conclusions

- The evaluation process showed that the inventory procedure produced accurate results for a wide range of stand types, as long as sufficiently large data sets are used.
- The cross-cutting simulation program performs rapid analyses in a familiar, user-friendly interface. It requires as inputs only the dbh and height data obtained in the pre-harvest inventory, an estimate of average stump height, and details of log specifications and values.
- The program faithfully mimics the process of cut-to-length harvesting and generates all of the information required by the timber procurement manager.
- Only the conventional stand parameters of dbh and tree height are measured and standard mensuration equipment, calliper and hypsometer, are used.
- The use of an electronic calliper allows for diameter data to be collected rapidly by an individual, and for the swift transfer of this information to a computer for subsequent analysis. Employing a laser-equipped height measuring device could improve the productivity of height measurement.
- The DSS that combines the inventory procedure, taper equation and simulation program provides a comprehensive insight into the yield potential of a stand.
- The pre-harvest inventory procedure developed in this project is relatively simple and meets the sawmill's requirements for efficiency and economy.

## References

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