

Allowing for risk in forward yield planning

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Summary

An alternative to the use of contingency allowances is described. It enables the level of cut to be set at the level that forest planners predict is appropriate, while explicitly allowing for the imprecision of the estimates.

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Introduction

The analysis of risk in forest management planning has become increasingly important. Forest managers commonly try to maximise economic returns and this generally means defining the objectives, determining an appropriate silvicultural management regime and then maximising wood flows, achieving these levels as early as possible.

Predictions of wood flows, however, are subject to a number of sources of error, and the risk inherent in estimates of forward wood availability must be managed. In the past, one common approach was to use a contingency allowance to reduce the estimate of available wood by a fraction based on the forest manager's perception of the risks involved.

This paper describes an alternative method that allows the predicted yield from a planning exercise to be fully cut while explicitly taking into account the underlying imprecision of the predictions.

The example described is a model with even wood flows over time. The method is equally appropriate for stepped wood flows or for wood flows that are based on criteria other than sustainability, but the diagrams would not be quite as simple and as clear.

Forward yield prediction

Estimates of wood flows into the future are always subject to imprecision. They may also be subject to some bias, although forest planners attempt to eliminate bias as far as possible. Imprecision can never be reduced to nil and there are many possible sources of error.

Some of the more important of these are listed below:

- at forest inventory
 - sampling error
 - plot location error
 - plot dimensions, area estimation
 - plot measurement error
 - site productivity variation
 - errors in the stratification, errors in strata areas;
- errors in calculating the volumes based on the inventory, including
 - errors in the tree volume calculations
 - errors in determining size and product assortments
 - errors in the taper functions or tree size assortment equations
 - errors in product classification
 - errors in the application of these models, for they may have been developed on quite different areas at different times and may have been based on forest stands grown under different silvicultural conditions from those now planned;
- errors in predicting growth;
- errors in predicting area changes;
- errors in modelling defect;
- errors in predicting site productivity for growth determination;
- differences between the mensuration methods used for predicting yield and log measurement not being appropriately accounted for;
- errors in the computing system(s) used to calculate the predicted yields.

The list is almost endless. In a simple sense there are two different categories of errors: those affecting the current inventory and those affecting the predictions of wood availability into the future; in essence, those affecting growth.

Quantifying the imprecision

Most forest planners have appropriate computer systems that will predict future wood flows for their forest estate, although there are considerable differences between the quality of the underlying data and models and therefore in the expected precision of the predictions.

Quantifying the imprecision in the modelled predictions of future wood flows is not simple and it will never be possible to precisely define a model for the imprecision in the predictions from the planning system. A simple estimate, however, is probably sufficient for most risk management studies, and the sources of imprecision can be grouped into the two separate categories defined earlier and separately quantified.

The first category is the imprecision in the estimate of what is actually there in the forest. It is not unusual to see a sampling error reported for an inventory, but it is unusual for any of the other error sources to be taken into account explicitly. An analysis (Leech and Correll 1993) of the inventory of the Woods and Forests Department of South Australia (now ForestrySA) radiata pine plantation resource quantified the sampling error for the total volume available, in any particular year of a cutting plan in the south-east of South Australia, at 3.1–4.3%. This could be considered typical for a reasonably-sized, well managed plantation forest estate with good forest management planning information and systems. Considering all the other sources of inventory error, especially measurement error, model error and application error, and taking these into account, then an estimate of inventory precision of $\pm 10\%$ at $p = 0.05$ is probably quite reasonable for a similar forest estate.

The second category is the imprecision in the estimate of forest growth. Leech and Sutton (1992) reported an analysis based on predicting growth on remeasured permanent plots from the first available volume measurement, and comparing the volume later in the rotation with the volume predicted by the model. The thinning regime was modelled based on actual stocking changes and the stands were not fertilised during the growth period. The growth prediction over the average 35-year growth period had a standard error of 9.5%. The 95% confidence limits are therefore about 20%, and a simple doubling of this standard error would seem quite reasonable for this example to account for other sources of error that are almost impossible to quantify.

The imprecision in the inventory is at a maximum at the start of the planning period, decreasing to zero over time as stands are clear felled and as the impact of the imprecision decreases. On the other hand, the imprecision in the growth predictions is applied annually and the effect over a long period is compounded and is approximately exponential, increasing over time from zero.

These two estimates provide a basis for a simple indicative model of imprecision. In this paper it has been assumed that planning indicates that there are 100 units of volume available per year and that, for convenience, these wood flows have been smoothed out by adjusting clear-felling ages or by some other silvicultural strategy. Based on the earlier estimates the 95% confidence limit for the inventory can therefore be modelled as 10 units, and the confidence limits for the growth projections over, say, 20 two-year periods and a rotation length of 40 years, can be estimated at 40 units (see earlier). Figure 1 describes this model. It must be stressed that this is an indicative model only, but not unreasonable.

The exact precision levels are not important for this paper as the intention is to demonstrate the approach, not make definitive comments about the specific levels of cut to be adopted. As mentioned earlier the approach would be equally appropriate for

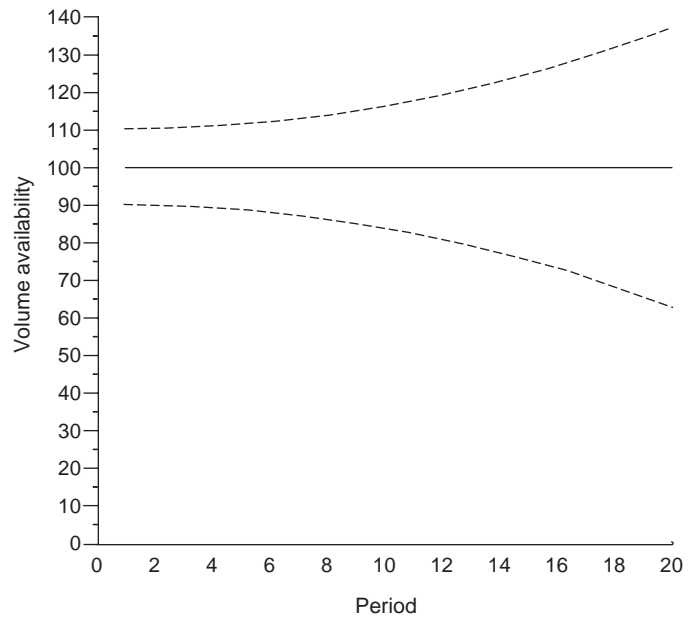


Figure 1. Indicative even-flow wood availability (—) and confidence limits (---)

stepped wood flows or for wood flows based on other criteria, but this example assuming non-declining wood flows is simpler to represent and discuss.

Identifying the question

The basic question to be addressed by forest managers and planners is relatively straightforward. Given the expected imprecision in forward wood availability estimates, at what level should the cut actually be set so as to appropriately allow for risk?

The question of risk management is made more difficult because the risk is two-sided, with the effect of the risk on each side being unequal.

If the market for forest products remains constant, then it is relatively easy to correct an under-estimate, as any extra wood that is later found to be available can be added to the available wood at a later time. The cost is simply the opportunity cost foregone in not cutting the extra volume earlier, although this may in itself be considerable.

Alternatively, it is far more difficult to correct the situation if the estimate is later found to be an over-estimate. It is commonly not considered appropriate to reduce the level of cut to the new level immediately as it might severely affect the industry and be imprudent politically. It is common in these situations to attempt to mitigate the effects of the correction by making the correction over a long period. If the original over-estimate was based on optimum silviculture and optimum forest management strategies that maximised growth, any variation from that particular silviculture required to resolve the planning problem would also result in less wood being available, further exacerbating the position. Measures to mitigate the effects could include planting new land, fertiliser applications, changing the utilisation standards, and implementing successful research that improves growth.

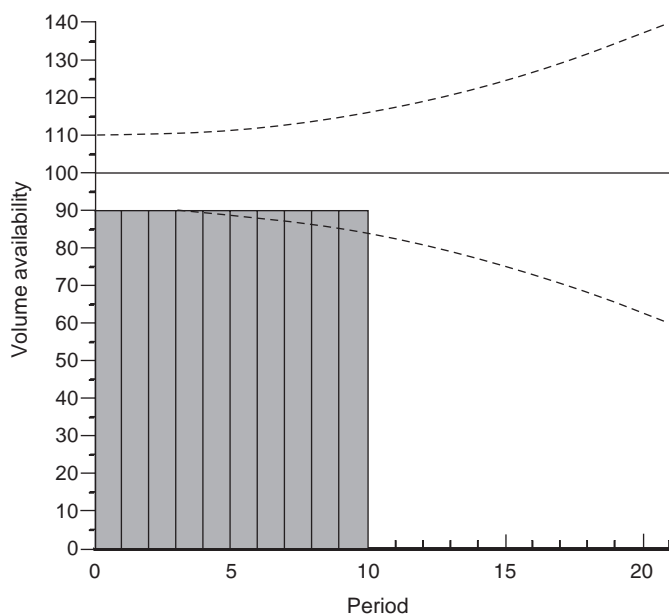


Figure 2. Indicative even wood flow (—) and confidence limits (---), with contingency allowance

Contingency allowance

In forest management planning it has been common to apply a contingency allowance and so reduce the volume to be harvested by an arbitrary fraction based on the perceived risk. In South Australian radiata pine plantations this was assessed as 10% in the 1960s, and therefore the contracts for wood were let at 90% of the estimated wood available.

It could be, and was, argued that this positioned the level of cut so that the perceived cost of the risk of over-cutting balanced the risk of under-cutting.

In the early 1970s, better forest mensuration information became available and this was built into an integrated forest planning system (Leech 1985). Forest managers found that the precision of the predictions was improved and the contingency allowance was reduced to 5%. This immediately allowed an expansion in sawmill capacity.

One difficulty in using contingency allowances is that, if the prediction models are later shown to be correct, the quantity of available wood builds up and this must be included in later estimates. If the forecast is an under-estimate then the build-up is even greater. Any such build-up could cause a delay in scheduled operations and this may mean that sub-optimal silviculture is applied in practice. This effect is lessened if wood availability is reviewed frequently, say at intervals of 5 years or less, and if the inventory and growth information available for planning is soundly based and precise, allowing the contingency allowance to be set at a low level.

If the pattern of wood availability is as shown in Figure 1, it is easy to infer that if the level of cut is set at say 90 units out of the 100 units of predicted availability, and if this level of cut is set for say 10 periods, then there is a slight risk that in the future there may be some difficulty meeting commitments. Figure 2 demonstrates that especially for periods 5 to 10 there is a risk in

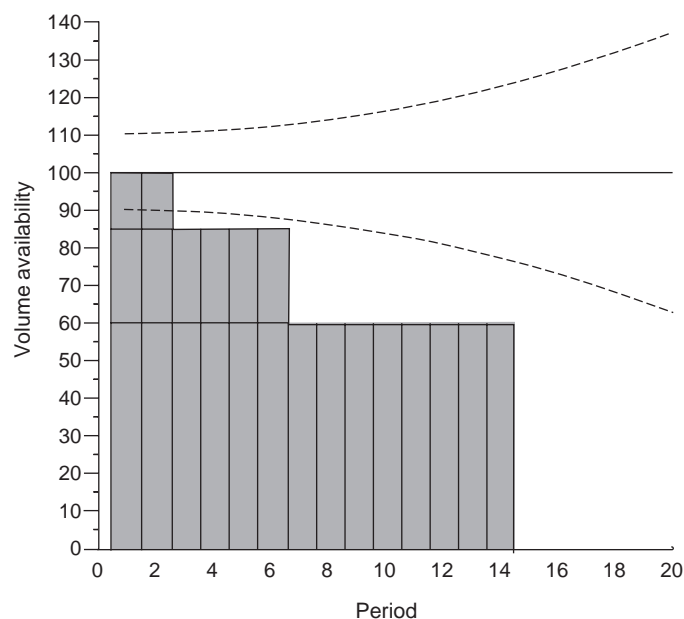


Figure 3. Indicative wood flow to provide a cut equal to availability for a period

that the cut will exceed the estimated 95% confidence limit level. In practice, however, it would be expected that the wood flow would be reviewed between periods 2 and 5, before that situation was reached.

If the contingency allowance was assessed at and set to 5% and the level of cut was set to 95 units, there would be a risk for all periods of any contract.

A time-based allowance for risk

Forest managers generally want to maximise wood flows and economic returns, and so they generally would prefer to cut at the predicted level of wood available and to operate with a zero allowance for contingencies. But risk has to be taken into account, and ideally it should be explicitly quantified. One way of achieving this objective is to vary the length of the contract period and to divide the wood available into contracts of unequal length. In effect this uses the contract length, or time, to help manage risk.

In this situation, wood supply contracts can be let for the total volume of wood predicted as available, but for periods of different length so that the combined risk is acceptable. Not all of the wood available is contracted for a long period of time.

Figure 3 shows one possible example where the total volume is assigned to three contracts:

- a long-term wood supply contract for 14 two-year periods at 60 units
- a medium-term wood supply contract for 6 two-year periods at 25 units
- a short-term wood supply contract for 2 two-year periods at 15 units.

Here, a purchaser would have a fixed, firm long-term commitment to a level of wood supply, and any necessary infrastructure development would be able to take place. The contracts would also allow the forest owner to commit all available wood.

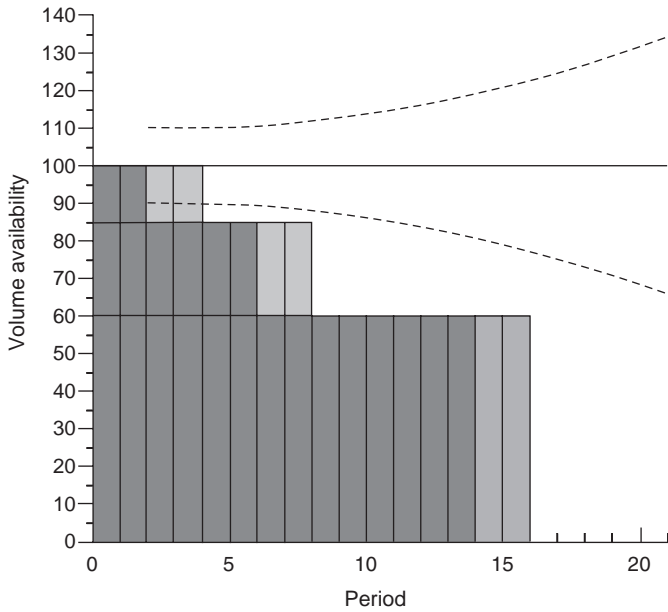


Figure 4. Indicative wood flows where subsequent analysis after two periods provides similar predictions of availability

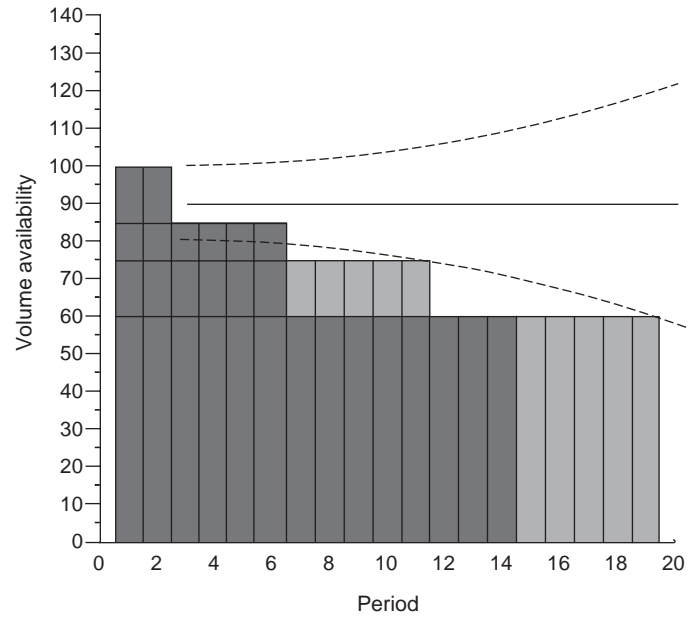


Figure 5. Indicative wood flows as for Figure 4, where availability is reduced in the future

In this example, apart from the first 2 two-year periods, the volume of wood contracted is always less than the perceived lower bound of the confidence limits. For the first 2 periods the total level of cut is 10 units above the lower confidence bound, but the area above the confidence bound is about the same as the area under the curve for the next 4 periods. Therefore the risk of over-cutting in periods 1 and 2 is balanced by a safety margin inherent in the under-allocation for periods 3–6 and beyond.

There is nothing fixed about the allocations defined in the figure, and the principle can be applied to assess whether the forest owner can deem any series of particular levels of wood allocation for particular lengths of time to be an acceptable risk or not. Further, the approach can be used to determine the maximum length at which a contract can be set to supply a particular volume of wood without occasioning undue risk.

Yield prediction is an ongoing process. If, for example, at the end of period 2 a recalculation of the wood availability provided estimates consistent with those obtained earlier, then the contract period could just be extended or the contract re-let. Alternatively, in the case of the short-term 2-period supply contract for 15 units, a new contract could be let. This is shown in Figure 4. If the two estimates were to be completely consistent then the length of the longer-term contract period could also be extended.

If the revision of wood supply after, say, 2 periods were to indicate either an increase or a decrease in wood availability, for whatever reason, then Figures 5 and 6 provide examples of revised levels of cut that would be possible.

Figure 5 illustrates one way of managing the effect of a decrease of 10 units in wood availability. The darker zone indicates the pre-existing commitments and shows that, if the predicted wood flow were to be reduced by 10 units, the pre-existing commitments could remain although the short-term spot sale would not be renegotiated. For periods 7–11 the medium-term contract for 5 periods would need to be set at a reduced level, perhaps at 15

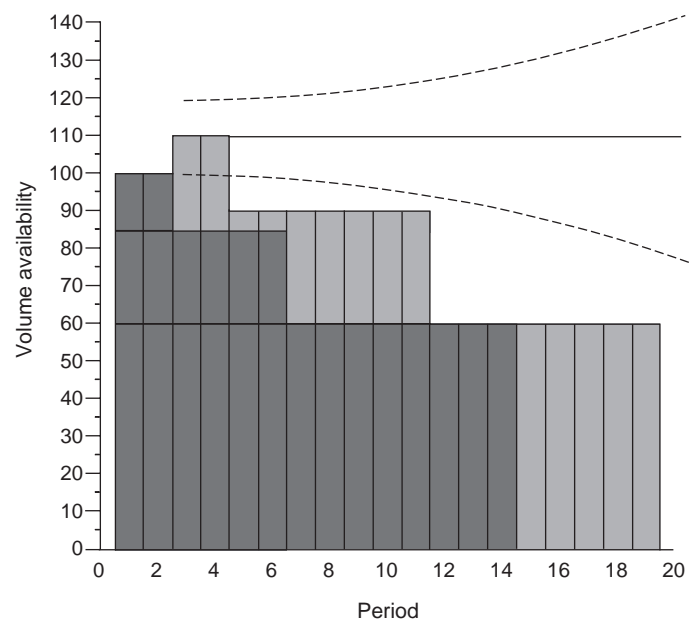


Figure 6. Indicative wood flows as for Figure 4 with availability increased in the future

units. There would be no wood available for a very short-term contract period.

The area under or over the lower confidence limit indicates the increase or decrease in risk in setting that level of cut, and in this case the level of cut is finely balanced with the lower confidence limit band. In this situation it would be prudent to take action to increase wood availability into the future, for example by land purchase, or fertiliser application or by improving silviculture.

Figure 6 shows the effect of the revised wood availability level being increased by 10 units. Again the darker zone reflects the then-existing commitments and the lighter zone illustrates one

possible way contracts could be let in the future. There could again be a short-term 2-period spot sale, this time of perhaps 20 units. The medium-term commitment could be renegotiated at the end of period 4 and increased to 30 units, the contract period being extended by perhaps a further 5 periods. The long-term contract to supply 60 units could also be extended.

There is a larger area between the lower confidence limit and the committed level of cut in the longer term for the increased level of cut, compared with the decreased model. It indicates there would be a larger safety margin in the longer term and that the levels of cut could be set with an inherently low level of risk. There is more flexibility for variation in Figure 6 than in Figure 5.

In both cases, however, the short-term level of cut can be set at the level the wood flow analysis predicts is sustainable in the long term, even though the level has changed.

These examples are based on even wood flows, but the principle can just as readily be applied to uneven wood flows. The principle does not imply sustainability, although the need for soundly-based risk management is more important if the objective is to cut at the highest possible level.

The principle can be applied whether the forest owner emphasises sustainability with even or non-declining wood flows, whether the forest owner has the philosophy of optimising wood flows, cash flows or net present value, or whether the emphasis is on short-term or longer-term objectives. The approach is independent of the actual precision of the planning process.

The principle could be used, for example, if a forest owner wishes to operate solely in the short-term spot market. The long-term wood flow model would remain and the owner could impute a particular average sale price per cubic metre, but would expect this to fluctuate over time. If the current market was to indicate lower prices then the amount of wood offered for sale would be reduced from the long-term average availability level. If higher prices were available then it would be appropriate to set a far higher level of cut so as to take advantage of the higher prices, while accepting that this would need to be accompanied by a decrease in sale volumes later when prices returned to, or fell below, the average. In essence the forest owner would be managing in an economically more risky environment but would be better placed to balance and to manage the risks involved.

Force majeure

These analyses were based on approximate 95% confidence limits. One question that is often raised is the ability of forest planners

and forest managers to handle devastating once-off changes to the forest, such as the effects of massive bushfires or insect or fungal attack.

It can be argued that there is no need to take these explicitly into account in setting the level of cut, as wood supply contracts should always include a *force majeure* provision that effectively allows for suspension of the contract if wood supply cannot be provided by reason of riots, civil commotion, earthquake, fire, catastrophe, Acts of God, changes in Government regulations or decrees, or (more importantly) by any circumstances beyond the control of the affected party which could not have been reasonably foreseen.

Given the wide-ranging provisions of a general *force majeure* clause in any wood supply contract, the use of a 95% confidence level would seem to be quite appropriate. Limited independent legal advice suggests that courts would agree with this proposition.

Conclusion

A time-based method is described that allows for risk when contracting to supply the total predicted level of wood available from a forest. The approach is intuitively more appealing than the use of contingency allowances. It enables the level of cut to be set at the level that forest planners believe is available, while explicitly taking into account the assessed imprecision of the estimates.

It must be stressed, however, that this is just one aspect of risk management and the exact manner in which the approach is adopted by any forest owner will depend on their objectives, their inventory data, growth data, models and systems, and on their corporate philosophy.

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