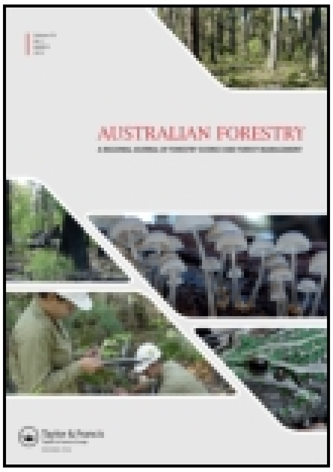

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Assessing sustainability in certification schemes

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Assessing sustainability in certification schemes

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Summary

This paper aims to provide guidance as to how better to assess sustainability in certification schemes, such as the Australian Forestry Standard, and to provide suggestions for related changes to certification guidelines.

The meaning of sustainability in relation to forestry and the principles underpinning sustainability and the calculation of sustained yield are examined to see how best they can be assessed in certification schemes, given the complexities of temporal and spatial change. To be useful in certification, such principles need to be capable of translation into auditable features, be they qualitative or quantitative. They also need to recognise the realities of demand and supply movements, landscape change, natural disasters, technological change and risk management. Forestry Tasmania's sustainable yield planning provides a case study that illuminates some of these issues, including the associated process of risk management.

The sustainability of jointly supplied environmental goods and services (e.g. wood and biodiversity) is more difficult to assess but also needs to be capable of audit—often involving, among other things, spatial assessment of conditions such as species diversity, fragmentation and connectedness and application of the precautionary principle.

Keywords: assessment; yields; sustainability; certification; standards; risk

Introduction

What is sustainability and how should we implement it in forestry? My interest in the topic (Ferguson 1996) was reignited by a request by the Programme for the Endorsement of Forest Certification (PEFC) schemes to review the sustainable yield of the Forestry Tasmania estate (Ferguson 2012), following an allegation of unsustainability by West (2012). Involvement in a major review by the Standards Review Committee of the Australian Forestry Standard in 2012 and 2013 highlighted the need for some changes in the then standard and prompted this paper. The review also prompted an examination of the related issue of applying the precautionary principle and then, in a larger leap, of the provisions relating to genetically modified organisms.

The aim of this paper is to review the issues of sustainability in the context of an audit for the Australian Forestry Standard and, in particular, the implications for the following:

- calculation of sustainable yield
- application of the precautionary principle.

In doing so, the aim is also to provide guidance on how better to assess sustainability in certification schemes and to suggest relevant changes to certification guidelines.

Assessing sustainability in forest management

The most widely cited definition of sustainability rests on the definition of sustainable development by the Bruntland Commission (1997, p. 1):

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

The central theme of this definition is intergenerational equity—fairness to future generations. Economists have grappled with this issue for many years because it bears on evaluations of investment, such as those involved in regulating forest harvesting, where we forego present consumption to invest in future consumption by later generations. Because long time periods of investment are involved, the discount rate plays a pivotal role in these evaluations.

Argument over the social rate of discount has a long history that continues today. Some time ago (Ferguson 1996), I rationalised that desire for intergenerational equity in valuing utility over time through consideration of the social rate of time preference, the discount rate that measures the relative preference for present over future consumption. Over the maximum time horizon for investment in general use (i.e. generally less than 50 years), the discount rate was assumed to follow the commercial value, but then to decline progressively thereafter until it reached a steady low state founded on our unwillingness to discriminate between the consumption of successive future generations in the far distant future.

Building on many earlier contributions, later research by Chichilnisky (1996) and Heal (1998) has strengthened support for that hypothesis. Heal (1998) describes this approach as seeking a balance between a 'dictatorship of the present' and a ‘dictatorship of the future’, and encompassing the complexity and goals of intergenerational equity. The dictatorship of the present refers to our evident propensity to want to consume now, rather than postpone that consumption—essentially a discounted utilitarian approach. The dictatorship of the future refers to our moral concern to see that we leave sufficient for future generations to consume—essentially a long-run sustainable utility approach.

While economics and discounting have frequently been the target of disparaging views by ecologists, among others, there are encouraging signs of a more realistic recognition of the philosophical and practical relationship between economics and ecology in relation to sustainability, well stated by a distinguished group of economists, ecologists and others (and succinctly put by Levin (2012)). They point out that the essence of sustainability is the need to ensure that ‘each generation … bequeath to its successor, at least as large a productive capacity base, relative to its population, as it had itself inherited’. This is very similar to the Bruntland Commission definition of sustainability cited earlier and a key point to be revisited later.

Boardman *et al*. (2011), in their recent book on cost–benefit analysis, expand on this approach, identifying four reasons to consider a time-declining discount rate for intergenerational projects—those with significant effects beyond about 50 years. Those reasons can be reduced to three, given the similarity of two of them.

1. In practice, individuals generally appear to be ‘time inconsistent’ in applying lower discount rates to far distant outcomes.
2. An ethical dilemma exists between being fair to future generations and economic evaluations that indicate that the value of discounted net benefits received 50 years and more ahead is generally trivial.
3. The further we look into the distant future, the greater the uncertainty that applies to what should be the discount rate at that point of time. If uncertainty about the real (i.e. inflation-free) discount rate is characterised in form of a set of probability distributions over time with progressively increasing imprecision (i.e. variance), the effect is for the certainty-equivalent[1] discount rate to reduce progressively much below the mean value of the discount rates—more so, the longer the time period concerned.

Based on research by Newell and Pizer (2003), Boardman *et al*. (2011) recommend real discount rates of 3.5% up to 50 years, declining progressively to 0% after 400 years. The last value, however, is inconsistent with the geometric mean of the underlying successive marginal social rates of time preference (see Ferguson and Reilly 1976) and is too low. A geometric mean involving high initial values of the marginal social rate of time preference, but ultimately going to zero in the far distant future, must approach a low but positive value, not zero, in that far distant future. While these cited contributions support the hypothesis I advanced long ago, it is by no means the last word on discount rates, as witness an alternative declining trend over time postulated recently by Weitzman (2010). Furthermore, the shadow pricing of revenues and costs in public investments to reflect other forms of market failure (Campbell and Brown 2003; Boardman *et al*. 2011) raises other issues.

The impact of discounting makes the social discount rate a major practical as well as philosophical issue in any consideration of public investments involving the far distant returns, as is often the case in forest management. Hence there is merit in seeking valuation and wood-flow scheduling practices in certification schemes that, as far as possible, avoid being mired in the uncertainties attached to the choice of discount rates in the far distant future, because these are not auditable against any firmly fixed scientific standard or basis.

Defining sustainable yield

The popular connotation of sustainability in forest management tended historically to focus on a constant supply of wood—THE sustained yield. This was a reflection of the simple ‘normal forest’ model underpinning a form of harvest regulation whose primary goal was to provide a stable harvest flow over time (Davis and Johnston 1987, p. 538). But the paths of our global, national and regional economies are characterised by constant change, for the most part involving population and economic growth over the long term, interspersed with major shocks and overlaid with marked cyclical fluctuations. Attempts to impose an absolutely steady supply over the planning horizon for a large forest estate therefore equate to trying to stem the tide. However, there is merit in having a set of supply targets for the estate that are not to be exceeded in the long run, subject to periodic review in the light of changes in markets, forests and knowledge.

In Australian forestry, sustainability is normally measured and expressed in terms of the ‘sustainable yield’. The term ‘sustainable’ probably in part owes its origins to an earlier inquiry (Ferguson 1985) in which I drew a distinction between the then widely used term ‘sustained yield’ and ‘sustainable yield’. The former implied a rigid target to be achieved. The latter implied a potential level, not necessarily a value that had to be maintained, but one that should not be exceeded over the long term: the point being that sustainability is not achieved by prescribing a single immutable value in the case of wood production (Ferguson 1996).

Sustainable forest management is concerned with the intelligent management of forest structures that are often unbalanced in terms of the uneven distributions of age classes and other forest conditions. Not every fluctuation can be perfectly smoothed out, nor should they be if they do not detract from the economic or sustainability goals. The essential question to be addressed at the end of the planning horizon is whether the forest will then be in a better condition than it is now. Translating this into a specific auditable goal is one of the key features of this paper.

[1]A certainty equivalent is the amount that would make the decision-maker indifferent between that amount and the outcome of a risky gamble such as is embodied in a draw from a probability distribution. A decision-maker with a certainty equivalent amount less than the mean of the probability distribution is said to be risk-averse, while one with a certainty equivalent in excess of the mean is said to be risk-seeking.

How we might best assess that condition is an important and evolving issue, and is discussed in a later section. A better future condition is the crux of the intergenerational equity issue that underpins the notion of sustainability developed by Chichilnisky (1996), Bruntland Commission (1997), Heal (1998) and Arrow *et al*. (2004, 2007).

Australian Forestry Standard definitions

The first Australian Forestry Standard (2007) defined sustainable yield as 'The yield that a forest can produce continuously at a given intensity of management' and clearly has shades of the old 'THE sustained yield' notion. However, later references in the standard made it clear that flexibility and adaptation is required. In the Australian Forestry Standard (2013, p. 15), sustainable yield is defined as follows:

> The maximum level of forest product that can be maintained for a defined period under a given management regime without reducing the long-term productive capacity of the forest. When the age class structure is in transition, the sustainable yield will differ from the natural growth. It is most relevant to large native forests and may have little relevance to small plantations.

The reference to 'The maximum level of harvest…' is somewhat misleading—it may be the maximum or it may be a good deal lower if the aim is to build up growing stock in order to supply increasing future demands or restore productive capacity. In practice, the level of harvest will likely vary with cyclical changes in markets. Although the definition lacks a clear link to the definition of 'sustainable forest management', the Standard does make the link to the Bruntland definition of sustainability in several places in ensuing sections, as illustrated below.

Criterion 4 in the Australian Forestry Standard (2013) states that 'Forest management shall maintain the productive capacity of forests and lands' and goes on to prescribe that

> The forest manager shall identify existing and potential productive uses of the defined forest area to support the maintenance of the long term productive capacity of the land.

Thus linking to the Bruntland definition of sustainability, it goes on to elaborate on this theme in Section 4.2 by noting that

> The forest manager shall identify harvesting rates for forest products commensurate with that long term productive capacity of the land.
>
> The forest manager shall consider:
>
> a. structure and condition of the forest
> b. estimates of sustainable yield
> c. social impacts
> d. markets, and
> e. optimal use of the defined forest area.

Section 4.3 goes on to require that the productive capacity of the forest is not compromised and that the forest condition, growth and harvest rates are monitored. It is followed by a sequence of provisions relating to infrastructure, silviculture, establishment, operations, fire and forest ecosystem health that underpin sound practice to maintain productive capacity; together with later sections dealing appropriately with soil and water resources, forest carbon, cultural values, and social and economic benefits.

In the light of the disconnect between the definition of sustainable yield and the later provisions that link to the Bruntland definition of sustainability, together with an ill-defined set of principles concerning the calculation of sustainable yield, the following principles replaced the earlier definition of sustainable yield in the new Australian Forestry Standard (2013, p. 20):

> The sustainable yield is a schedule of planned wood flows to be harvested over an extended planning period in order to meet the objective of the organisation—normally, to achieve the greatest present value of discounted net cash flows for a commercial entity, but which can sometimes be simplified to the greatest even-flow of wood subject to:
>
> - applying the relevant contractual and other supply commitments, silvicultural regimes, and operational considerations
> - maintaining management and protection of the estate during any intervals in which wood flows cease or are markedly reduced
> - ensuring that, at the end of the planning period, the forest as a whole is left in a better, or at least as good a, condition for future generations as at the start of the planning period, in terms relevant for productive capacity and other values
> - conducting periodic reviews to update the forest inventory and re-calculate sustainable yield, especially in order to adapt the Forest Management Plan to any unexpected changes since the last review.

The first principle is a practical requirement that reflects a raft of clauses already in the guidelines of the standard and summarised earlier. The second is important because harvesting may be intermittent in some cases and evidence is needed of a commitment to maintain management and protection during those pauses. The third is the epitome of sustainability. The metrics will vary widely with the estate but might include structural goals (distributions of size or age classes and forest types) and, with further development and research, illustrations of changes in biodiversity, fragmentation and connectedness. The fourth is self-evident because none of the preceding principles can be achieved without a proper and current forest inventory. All of these principles were either explicitly or implicitly in the former standard or the guidelines, and the change in the definition simply serves to strengthen and summarise those principles in the new standard.

The present and future condition of the forest can be examined in terms of the present and predicted distribution of age classes, stand structures and forest types, and this has been done by Forestry Tasmania (2011b) in recent analyses. In Western Australia (Ferguson *et al*. 2001), structural goals have been prescribed for the end of the planning horizon. With the development of more sophisticated geographic information systems and modes of temporal and spatial analysis, that process may be refined further over time to examine spatial distribution goals, such as those relating to fragmentation, connectedness and diversity at the end of the planning horizon.

Calculating sustainable yield

The principles described above underpin the calculation of sustainable yield. Neither the Australian Forestry Standard documentation nor the PEFC documentation provides details of how sustainable yield for wood production might best be calculated. A standard cannot prescribe the details of how that calculation should be done because there are too many variants in forests and their associated economic, environmental and social conditions.

Considerable literature exists on the technical aspects of this topic because it is at the core of the sustainable management of almost all large forest estates. The most recent major works on the calculation of sustainable yield are those by Hof (1993), Buongiorno and Gilless (2003), Amacher *et al.* (2009), Bettinger *et al.* (2009) and Weiskittel *et al.* (2011). Regrettably, none address sustainability in the context of setting specific goals to be assessed under certification schemes.

So how is sustainable yield calculated? There are basically three methods, although mostly the latter two are jointly involved:

- Sustained yield formulae: These are historic and are generally used today only as very crude gross error checks.
- Simulations: These are techniques that take the present forest inventory data and predict future growth, based on a set of assumed silvicultural treatments, supply constraints and harvest levels. In practice, the process is repeated several times, each using a different set of options until an acceptable and sustainable path is obtained.
- Constrained optimisation: These techniques use a simulation model to develop the data needed to investigate many options at once and to select the best of those mathematically using linear programming or similar techniques.

The mathematical construction of the constrained optimisation model is complex and has evolved into a highly sophisticated system as more detailed inventory data, faster computing systems and better optimisation algorithms have been developed. Spatial integration with remote sensing and geographic information systems has provided much greater accuracy in basic land-use data but has added complexity. Most commercial forest planning models use linear programming to solve the constrained optimisation problem, for which well-developed commercial software[2] is available.

Most large forestry entities use constrained optimisation, as does Forestry Tasmania (Whiteley 1999; Riddell and McLarin 2003). Terms like 'constrained optimisation' may summarise the mathematics succinctly but obscure the essential elements from the general reader and hence a brief summary of what is generally involved in 'best practice' may help.

The first step is to identify the areas on which wood production is permitted, thereby excluding formal and informal reserves from the calculation of the sustainable yield of wood production (e.g. Forestry Tasmania 2011a). Formal reserves are those created under legislation, such as national parks and the like. Informal reserves are those stipulated under regulations such as the codes of forest practice and involve stream buffers, wildlife corridors and local reserves to protect rare or endangered species.

The second step is to identify the nature of the objective for wood production. More importantly, what constraints are to be placed on this maximisation, and over what planning horizon (Forestry Tasmania 2011b)?

Most large commercial forestry organisations maximise discounted net revenue[3] because this enables a link to the valuation of the estate for accounting purposes, albeit subject to some peculiarities of the accounting standards (Ferguson and Leech 2007; Leech and Ferguson 2011). It has further advantages in the prediction of cash flows and monitoring the risks of future solvency.

The Auditor-General of Tasmania (2011) recommended that a risk-free rate of discount be adopted in the valuation of Forestry Tasmania and suggested targeted rates of return of 2–3% on assets might be appropriate, given particular conditions. The Auditor-General stressed, however, that 'this should not be taken as our agreeing that returns of 2–3% should be regarded as acceptable particularly over the longer term' and noted that the choice of discount rate was a matter for Forestry Tasmania to justify. This opens the way for consideration of the earlier discussion about the social rate of discount.

As argued elsewhere (Ferguson 2009), extending the planning horizon beyond 50 years seems to stretch credulity, given the uncertainties attached to predictions beyond 20 years. Nevertheless, in adopting a 90-year planning horizon, Forestry Tasmania has implemented measures to ensure that the condition of the forest is improved at the end of the horizon, relative to the start, based on comparisons of the forest structures and distributions of age classes. This and the Western Australian practice of setting specific structural goals at the end of the planning horizon constitute worthy initial examples of implementing specific sustainability targets as constraints on the scheduling of wood flows.

About 400 years ago,[4] John Evelyn (1670) introduced into the English language the already established German notion of the 'normal forest' where an estate is divided into a number of coupes with equal potential, with one part harvested each year, so that the forest and yields are in a steady state. Once a forest has achieved this steady state, further simulation is unnecessary, because—except for force majeure—the yield will remain constant. Whilst the notion of a normal forest is a theoretical one that is rarely attainable in practice, it shows that if the condition at the end of the planning horizon is near to a 'normal' steady state, future sustainability of the estate in

[2]Woodstock is a commonly used software package that provides simulation input into a linear programming model, among other things.

[3]Some large state-owned organisations use maximising an even flow of wood as their objective. The distinction between this and maximising discounted net revenues is not as critical as it might seem because the constraints placed on the objective generally dominate the solution, especially where those constraints ensure that the condition of the forest at the end of the planning horizon is improved over that at the start.

[4]I am indebted to Jerry Vanclay (personal communication) for this elegant reminder.

terms of timber production is assured. The time taken to reach a near-normal steady state depends on the initial condition of the forest, the harvest strategies to be imposed over the planning horizon and the growth rate of the forest. Whether the near-normal condition also demonstrably meets the Holling requirements for ecosystem resilience and stability is a matter to be explored through the examination of appropriate metrics (Common and Perrings 1992), most of which are readily available or capable of ready estimation.

A planning horizon of 50 years or so also has the advantage of enabling the use of a constant discount rate, most probably based on a generic weighted average cost of capital because, under the hypothesis advanced earlier, there is little change in the marginal social rate of time preference over that period. The valuation would then also be consistent with Australian forest valuation guidelines[5] (Leech and Ferguson 2011).

Instead of setting an explicit sustainability goal, a commonly used practice is to set a 'non-declining flow' constraint (Davis and Johnson 1987). As Hof (1993) points out, non-declining flow almost always results in a capacity to increase productive capacity at the end of the planning horizon. However, it does so in a manner that does not involve setting an explicit and therefore transparent goal for sustainability. Moreover, it results in a static level for wood flows from the time of implementation onwards. For commercial entities, this may be especially disadvantageous because much of the aggregate discounted net revenue arises from the first five or so years of the planning horizon. Variation of the harvest over that time to take best advantage of market conditions is therefore advantageous and is consistent with Australian Forestry Standard's guidelines cited earlier. Annual or periodic revision of the calculation of wood flows and valuation is an essential part of the process; any change in the sustainability goals normally being to their betterment, unless natural disasters render that impossible.

The major silvicultural options affecting harvest yields such as thinning, clear-felling, selective harvesting, regeneration, planting and pruning need to be identified for scheduling of wood flows. For a particular planning period, only particular stands will be old enough to carry out these harvest operations, so there are a plethora of area constraints for each of the nine 10-year planning periods in the Forestry Tasmania planning model. These generally set upper and lower bounds on the aggregate volumes of wood harvested from particular regions or on special timber species, based on market forecasts relating to the demand for wood of various qualities and properties, together with those maintaining viable minimum supply levels under contracts and legislative agreements. And there are constraints on the silvicultural regimes to mitigate negative impacts on environmental services such as landscape aesthetics or wildlife habitat (Burgman *et al*. 1994).

[5]The terminal value of the estate at the end of the horizon can be estimated either by using the current valuation as a proxy or by applying von Mantel's sustained yield formula (Davis and Johnston 1987) to estimate the wood flows, applying an average net revenue to estimate net revenue flow and discounting that net revenue stream back to the end of the planning horizon.

Of course, no solution from such a seemingly 'black box' exercise[6] should be accepted on face value, and hence the need for public consultation and for periodic audit and review, to adapt to changes in conditions and knowledge, and to incorporate more recent data and knowledge. The Australian Forestry Standard and guidelines require consultation with and meaningful participation of stakeholders, as well as periodic audit and review.

Allowing for risks in calculating sustainable yield

The constrained optimisation and simulation techniques described above are primarily deterministic in character, such that a given set of inputs leads to only one set of harvest schedules to apply. But all management systems involve risks because perfect information eludes us and hence risk management is an important complementary and oft-neglected part of determining the sustainable yield.

The risk that commercial managers most fear is that of insolvency—the inability to pay bills when due. That risk is one reason that constrained optimisation and simulation models are widely used. In addition to providing a sustainable yield in the form of a harvest schedule, these techniques enable cash flows to be predicted over time and the associated risk of insolvency to be gauged in planning and negotiating future debt and other financial arrangements. There are various ways of examining the potential risks, ranging from simple sensitivity analyses to stochastic analyses using Monte Carlo techniques (e.g. see Ferguson 2009, 2011). Commercial software (e.g. Woodstock, *op. cit.*) makes some provision for Monte Carlo techniques. Future development of these models is likely to see much greater and more sophisticated use of such techniques, including the use of the so-called 'genetic evolution' algorithm for stochastic constrained optimisation (e.g. Chikumbo and Nicholas 2009; Chikumbo 2011). However, in most cases the treatment of risk and uncertainty is idiosyncratic rather than systematic. The aim of the next sections is therefore to describe and differentiate between various sources of error and so provide some clearer guidelines for the calculation of sustainable yield in relation to risk management.

All calculations of sustainable yield are subject to errors, variously ascribed to risk or uncertainty, some of which reflect the fact that Forestry Tasmania cannot measure every tree in the forest and so use a sample of plots on which the trees are measured to estimate the standing volume and other characteristics. Even if they could be measured, uncertain events that influence the standing volume could be predicted. Forestry Tasmania periodically re-measures some of those plots to estimate growth (Whiteley 1999; Riddell and McLarin 2003), thereby providing sample-based estimates of growth and yield in the form of functions that relate the standing volume to key variables (e.g. age, stocking, site) that influence the relationship. The accuracy of any calculations of sustainable yield rests on these functions, among other things, and can be assessed using two criteria—bias and precision.

[6]A black box is a system which can be viewed in terms of its input, output and transfer characteristics without any knowledge of its internal workings (after Wikipedia, 2 August 2013).

Corrections of predictive functions for bias

Bias refers to the difference between the estimated mean and the true value. As Brack and Vanclay (2011) point out, the ultimate goal is to eliminate bias as far as possible in the calculation of sustainable yield. This includes accurately measuring the net productive area of forest by eliminating permanently unproductive areas, such as those in formal and informal reserves or sites inhospitable to commercially viable tree-growing.

Various corrections (referred to as 'discounts' in the Tasmanian literature) to remove biases in the plethora of growth and yield functions involved were implemented in recent revisions of the Tasmanian planning process (Riddell and McLarin 2003; West 2007, 2008). Some sources of area corrections, such as stream buffers, are quite specific and stable. Stamm (2011a, b, 2012) undertook a detailed assessment of net productive area and other corrections for the Forestry Tasmania estate. He found that there has been little change in the average area correction across all forest districts (about 24%) since 2007, notwithstanding some increases and some decreases in individual districts over that period. Burgman and Robinson (2012) checked and applied similar corrections in a thorough and appropriate manner for the individual areas involved in the intergovernmental agreement in Tasmania.

Corrections for imprecision

Precision reflects the fact that there are inherent sources of random variation in the estimates, even after any bias has apparently been removed. This partly is a result of sampling, instead of complete enumeration, of the trees in the forest.

Precision can be gauged by the variance or the standard error of the distribution, if the bias has been removed or is negligible. Estimates of the precision attached to the 2007 estimates of total sawlog volume were calculated and the errors found by Brack and Vanclay (2011) were 'small enough to allow useful estimates' of harvest yields and therefore, ultimately, for calculating sustainable yield. Most audits focus on the precision of the aggregate standing merchantable sawlog volume because that is a key determinant of any sustainable yield.

Typically, the desirable confidence limits (i.e. precision) of the estimated aggregate volume is that they should at least lie within ±10% of the aggregate at the 95% probability level. But this is a crude criterion and much greater precision may be needed where other species and log grades are involved.[7]

The magnitude of these measurable (and other) risks may influence decisions taken about the choice of sustainable yield. For example, suppose for the sake of argument that the 10% confidence limits imply a set of confidence limits around the sustainable yield of similar magnitude.[8] What safety margin[9] should the decision-maker apply in choosing the final value of sustainable yield to be set in negotiating harvest contracts, given that there is a 1 in 20 chance that the actual aggregate volume lies outside those confidence limits? Large growers commonly enter into legally binding contracts to supply particular quantities of certain log assortments to individual buyers and these represent a potential liability to the grower if unable to meet the contracted supply, although there may be 'force majeure' escape clauses for exceptional cases, such as natural disasters and wars.

Safety margins are essentially risk premiums or forms of self-insurance and are or should be the certainty equivalent value of the risk involved. A certainty equivalent is the amount that makes a decision-maker indifferent between it and the potential outcome of a risky investment or decision. The safety margin to be used will depend on the grower's attitude to risk of insolvency or other risk as well as nature and severity of the potential liabilities. A certainty equivalent safety margin will hinge crucially on the decision-maker's attitude to risk.

A grower's attitude to risk can pose a dilemma for a commercial state-owned entity such as Forestry Tasmania. As noted earlier, the Auditor-General of Tasmania (2011) has indicated that a risk-free rate of discount should be used in valuation of the Forestry Tasmania estate. This follows a well-established economic principle that if the Forestry Tasmania contribution to state investment is small and its returns statistically independent of those for the state economy as a whole, a public entity should be risk-neutral in discounting (Arrow and Lind 1970). On this basis, risk-neutrality would be appropriate in gauging the safety margin applying to the discount rate for any similar commercial state-owed entity, making the safety margin effectively zero. However, the Forestry Tasmania Board and senior executives might have a very different attitude, because of the risks involved to their reputations, and might therefore apply a safety margin on that account. These are matters for the Auditor-General and Forestry Tasmania to resolve. Nevertheless, for a large commercial state-owned entity, there is a valid argument for a risk-neutral attitude or, at least, only a very small amount of risk aversion in setting a safety margin. The same cannot generally be said for privately owned entities. Of course, there are other ways of hedging against these measurable risks, such as using rolling-average harvest yields, but these simply highlight the need for a much closer analysis of the attitude to risk and the consequent choice of safety margin. Leaving aside the different role of a state auditor-general, certification auditors need to understand the attitude to risk used in setting the sustainable yield, and hence to assess the basis of the safety margin used.

In the discussion to date, most of these assessments concern 'measurable risks' that are embodied in the normal processes of forest inventory and estimation of growth and yield functions but they do not constitute an exhaustive list of the risks to be considered, some of which are seemingly unpredictable.

Corrections for seemingly unpredictable risks

In terms of major seemingly unpredictable risks in Tasmania, at least two potential 'elephants in the room' loom large. One relates to wildfire and the other to market acceptability of eucalypt plantation sawlogs and veneer-logs.

[7]Statisticians will also appreciate that in looking at the accuracy of functions, trade-offs between bias and precision are sometimes needed.
[8]Normally, as we shall later show, they will be substantially smaller.
[9]Burgman and Robinson (2012) use the term 'headroom' but this has other connotations in financial circles, often being used to describe the safety margin to be employed for interest cover ratios.

Wildfire

The utilisation of native forest produce from stands of regrowth and remnant old growth extends over a considerable period in Tasmania, providing considerable experience for the native forest industry as to the costs involved, the market acceptance of the various qualities of the ultimate produce and the prices needed to support viable operations. With the exception of major wildfire, most of the impacts of pests and diseases, small fires, coupe dispersal, creation of informal reserves and environmental constraints are either reflected in the inventory and planning data or can be simulated and estimated via geographic information systems. As Burgman and Robinson (2012) note, small fires are of little long-term consequence, because the salvage operations can, for sawlogs and peelers, be substituted for currently scheduled coupes and the longer-term harvest pattern rescheduled.

Catastrophic fires[10] pose greater problems in allowing for risk because of the extent and volumes involved, especially given the possible impact of climate change. Burgman and Robinson (2012) note the potential of major wildfires on the calculation of sustainable yield. Some research has been done on the mean interval between major fires in Tasmania but is handicapped by the limitations of the historic data and the cost of the alternative methods of fire dating (Marsden-Smedley and Whight 2011).

Although seemingly unpredictable, wildfire occurrence and attendant risks can be simulated by constructing models that embody the probabilities of occurrence of a fire and the probabilities that, once ignited, it will reach a particular size (e.g. Ferguson 2009, 2011). For the Forestry Tasmania estate, due recognition would have to be given to the marked regional differences involved in climate, fragmentation and forest types. Modelling could also be extended to examine the risks to plantations, although the probability distributions involved would differ.

Eucalypt plantation sawlogs and veneer-logs

The Forestry Tasmania strategy, dating back at least to the 1997 RFA report, has been to reduce progressively the harvesting of old-growth forest, replacing it by harvest from regrowth forest and plantations. However, experience in processing of the produce of eucalypt plantations was, and in some cases still is, quite limited. This means that there is a substantial potential risk to the processors of eucalypt plantation timber pertaining to the properties and consequent costs and market acceptability of the produce, and consequently, to Forestry Tasmania in the amount of wood and the price it can command for that wood.

Earlier estimates by Forestry Tasmania (2007) were predicated on the assumption that, given early pruning and moderate thinning, *Eucalyptus nitens* and possibly *E. globulus* plantations would provide sawlogs of suitable quality to yield timber acceptable in the marketplace in competition with that from native forest and pine plantation. The experience of the Forestry Enterprises Australia sawmill, while seemingly successful in overcoming some of the seasoning problems, suggests that the product had not met market expectations at a viable price (Poyry 2011). That experience, however, involved the use of younger unpruned logs. Nevertheless, as Brack and Vanclay (2011, p. 5) point out, ‘while the models may reliably predict the total volume of timber, “pushing” the system to ensure all the veneer material is produced may impact on the amount of sawlog produced’.

Burgman and Robinson (2012, Appendix 2) canvassed these issues at length and concluded:

> The question of how much risk is acceptable, who should bear the risk, and what are efficient mechanisms for sharing the risk, are critical ones that the participants of the process must resolve if the eucalyptus plantations are to be considered among the sources of product.

Subsequently, the Forest Industries Association of Tasmania (Forestry Tasmania 2012, Attachment B) expressed some concerns about the acceptability of plantation-grown *E. nitens* but more recently (FIAT 2012) has recognised that plantation-grown pruned logs can meet the existing definition of ‘high quality sawlog’.

Only time and experience will resolve the issues of the choice of regimes and ultimate market acceptability. At present, considerable uncertainty and risk clearly attaches to the outcomes. While it is reasonable to recognise, as Harwood (cited in Forestry Tasmania (2012)) argues, that these issues will be resolved over time, another 10 years to perhaps 20 years will be needed before such fundamental issues are resolved. Thus the Forestry Tasmania (2007) safety margin of 10% appears too low and the Burgman and Robinson (2012) use of 30% may be appropriate for the next 20 years. However, a 30% safety margin beyond the next 20 years may be too high because there is a reasonable likelihood that many of these issues will be resolved.

As indicated earlier, a stochastic analysis based on the views of processing experts would be useful in translating the somewhat arbitrary estimates of safety margin into a more appropriate treatment of impact of the risks involved, most likely aiming at prescribing that there be (say) a 90% probability of being able to supply a specified annual volume over a particular period.

Failing a stochastic analysis that enables the odds of breaching the contract to be evaluated, the application of a safety margin is a pragmatic choice that often aims to minimise the maximum risk, especially of insolvency. That choice needs to make a clear distinction about the various sources of risk and a certification auditor needs to assess whether those various sources of risk have been recognised appropriately.

Biodiversity risks and the precautionary principle

Another source of risk stemming from the commitment to biodiversity conservation and the maintenance of environmental services in the standard relates to the precautionary principle. The 2007 Standard referred to this principle in the Introduction on page 3 and defined it as follows (Australian Forestry Standard 2007, p. 13):

[10]As a recent editorial in *Nature* (Anon. 2013a) points out, there are other potential catastrophes (e.g. super-volcanoes, apocalyptic tsunamis and mega solar flares) that could devastate the biosphere and human society. Besides being unpredictable, the outcomes will be out of our hands, so there is no point in worrying about them.

> Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

This is a truncated version of the definition used in the *Intergovernmental Agreement on the Environment* and in the *National Forest Policy*[11] which adds:

> In the application of the precautionary principle, public and private decision should be guided by
>
> 1. careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment, and
> 2. an assessment of the risk-weighted consequences of various options.

An article by Randall (2009) provides a useful model as to the interpretation of the two guidelines cited above. It recognises that there are (1) threats that have massive (disproportionate) and irreversible (asymmetric) consequences, and (2) threats of lesser consequences where the risk-weighted consequences in the missing addendum above ought to be evaluated and used to shape the decision. The definition of the precautionary principle in the new Australian Forestry Standard (2013, p. 15) therefore now reads:

> Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In applying the Precautionary Principle, decisions should be guided by:
>
> - scientifically credible evidence of a threat, and
> - assessing whether the threat is irreversible and/or disproportionate; if so, applying a remedy sufficient to prevent that threat arising, otherwise, making a decision on an assessment of the risk-weighted consequences of various options.

In making any assessment of the risk-weighted consequences, the opportunity costs involved in reducing productive capacity need to be considered as well as the impact on the biodiversity or other environmental service. For example, some of the area safety margins (the so-called 'discounts' of Burgman and Robinson (2012)) under the Tasmanian *Code of Forest Practice* proposed since 2007 are of an 'umbrella' character that reflects difficulties in precisely specifying boundaries in the implicit trade-offs between the commercial management for wood production and the largely non-commercial supply of environmental services.

Table 1 shows some personal estimates of the volumes of various products sold by Forestry Tasmania and their prices at stump.

The actual values of volumes sold and stumpage are not available publicly and hence the values in Table 1 are only very rough approximations. Furthermore, they assume that the particular reduction corresponding to the area lost times the average annual increment in volume.

The resulting opportunity costs in Table 2 have been calculated both in annual value and present value terms, the latter being based on a social rate of discount of 5% applied over a planning horizon of 90 years. Applying a lower discount rate, as recommended by the Auditor-General of Tasmania (2011), would greatly increase the present value of the opportunity cost. A 90-year planning horizon conforms with Forestry Tasmania practice. Shortening it would not materially affect the results.

Table 1. Estimated Forestry Tasmania sales and revenue

Product	Approximate volume sold ('000 m^3 $year^{-1}$)	Approximate stumpage (\$ m^{-3})	Approximate total revenue ('000 \$ $year^{-1}$)
High-quality sawlogs	238	58	13 800
Other sawlogs	67	42	2 814
Peeler logs	216	35	7 560
Native forest pulplogs	2 004	19	38 076
Totals	2 525		62 254

Source: Personal estimates based on the 2009–2010 values for forest sales (Forestry Tasmania 2010)

Table 2. Opportunity costs of reductions in Forestry Tasmania's sustained yield

Item	Amount
Mean opportunity cost	\$24.66 ha^{-1} $year^{-1}$
Sustained yield according to Forestry Tasmania Act	330 000 m^3 $year^{-1}$
Opportunity cost per 1% lost in sustainable yield	\$81 362 $year^{-1}$
Present value of opportunity cost for each additional 1% loss in sustained yield @ 5% discount rate	\$1 627 233

The opportunity cost in Table 2 is based on the marginal revenue foregone, not the marginal net revenue. However, the labour inputs involved in applying these new provisions would be substantial and would not be incurred in the alternative, so this may be a reasonable and possibly even a conservative estimate. Nevertheless, the estimate illustrates the order of magnitude of the average opportunity cost over the Forestry Tasmania native forest estate of an additional 1% discount relating to such an environmental trade-off.

Rounding down the values in Table 2, each 1% per unit of sustainable yield reduced constitutes an average opportunity cost of about \$80 000 per year or a present value, when discounted at 5% over a 90-year period, of about \$1.6 million. Based on a very crude approximation using the Von Mantel sustained yield formula for a 'normal' forest (see Davis and Johnston 1987), a reduction in the aggregate area of a large forest estate results in up to double that reduction in sustainable yield, while a reduction in volume only results in up to an equiproportionate reduction in sustainable yield. Thus, those changes in sustainable yield that derive from area discounts could be only half those amounts per additional 1% in area reserved.

The recent proposals for changes to the Tasmanian *Code of Forest Practice* reflect research and expert advice and merit

[11]See http://www.daff.gov.au/__data/assets/pdf_file/0019/37612/nat_nfps.pdf

attention in the future code. However, alternative solutions might achieve the same outcome at a lower opportunity cost. For example, does the particular provision need to apply over the entire 90-year period? Time-limited (5-year) provisions like adjacency constraints have a very much lower impact on sustainable yield, if correctly applied. Does the provision need to apply to the entire estate or could it target relevant portions separately, reducing the overall impact? Are there alternative incentives or penalties that can achieve the same outcome at a lower opportunity cost?

A certification auditor needs to assess whether measures to protect biodiversity against threats that are not irreversible and/or disproportionate have taken account of the opportunity costs involved.

Risks posed by pests and diseases

The recent introduction of myrtle rust (*Puccinia psidii*) and the advent of apparently new mutant forms of *Phytopthora* in the United States, Chile and Great Britain all point to the potential risks posed by the introduction or development of new pests and diseases to existing native or commercial biota. While tightening of phyto-sanitary measures is one sensible response to the potential risks of new pests and diseases to Australia, greater consideration needs to be given to the advances that have taken place in genetic diagnostics and the development of transgenic plants to combat the potential and actual risks involved.

The definitions of the 2013 Australian Forestry Standard (2013, p. 15) contain a useful definition of genetically modified trees. This topic is well known for raising soundly based concerns as well as passions. Whatever is done in introducing genetically modified trees and associated biota clearly needs to be strictly regulated and controlled. Nevertheless, the aspirations of Merkle *et al.* (2007) to restore threatened species through transgenic work are reaching fruition in terms of experimental plantings of resistant hybrids of chestnut (Anon. 2013b) and research is proceeding on other exotic pests and diseases. However, Clause 3.8 INTRODUCED GENETICS of the new Australian Forestry Standard (2013, p. 29) contains a very strong statement that

> The forest manager shall not use [plant or sow] genetically-modified trees.

Shutting the gate as firmly as does Clause 3.8 denies the potential for mitigating the threats posed by new pests and diseases to some native and commercial tree species. In the case of *Phytopthora*, resistant strains of the host tree species seem to be available. The experience in human medicine suggests that genetic diagnostics and subsequent transgenic manipulation to enable the development of resistant strains may offer the most rapid and effective method of countering this threat. The following proposed change to the standard was rejected by the Standards Review Committee, but warrants reconsideration in later revisions, provided the relevant legislation offers effective control on the possible threats that may be posed in relation to the introduction of transgenic plants:

> The forest manager shall not plant or sow genetically-modified trees unless to counter an otherwise irreversible and/or disproportionate threat posed by an introduced disease or pest using genetic modifications that are scientifically and legally justified.

It warrants reconsideration in later revisions of the standard, provided the relevant legislation offers effective control on the possible threats that may be posed in relation to the introduction of transgenic plants, as it would seem entirely consistent with the precautionary principle of 'applying a remedy to prevent a threat arising'.

Conclusions

Sustainability is essentially about intergenerational equity—fairness to the generations to follow. While the economic theory underpinning the analysis of intergenerational equity is well developed, its application for the purposes of certification is mired by the debate over the appropriate rate of discount. To avoid this issue, a realistic relatively short planning horizon (say 50–80 years) is recommended, together with setting of specific sustainability goals so as to leave the forest in a better, or at least as good as, condition at the end of the planning horizon. The sustainability goals for wood production would be based on prescribing stand structures or the distribution of age classes, together with appropriate metrics prescribing the sustainability goals for biodiversity and other ecosystem services. For commercial wood production, a goal of maximising discounted net revenue, subject to constraints set by the sustainability goals, is then appropriate and the calculations have side benefits with respect to valuation, predicting cash flows and monitoring future risk of insolvency. The methodology also provides the flexibility to adapt to market changes, natural disasters or unforeseen shocks through constrained optimisation and periodic re-assessment.

The Australian Forestry Standard has been widely accepted and its guidelines for the calculation of sustainable yield allow and indeed encourage the adoption of this new approach to the calculation of sustainable yield.

Three specific and important changes concerning the definition and calculation of sustainable yield and the treatment of precautionary principle were considered and adopted in the new Australian Forestry Standard (2013). One concerning genetically modified organisms, that also rests on the precautionary principle, was not adopted. All seem equally applicable to the Forest Stewardship Council Standard. In addition, some guidelines were suggested to assist certification auditors in their role of assessing whether forest management practices meet the intent of the standard in ensuring 'best practice'.

The Australian Forestry Standard is internationally recognised under the *Pan-European Forest Certification* scheme and represents an alternative form of certification to that offered by the Forest Stewardship Council, which has very similar guidelines and aspirations. Both have merit in providing mechanisms for ensuring continuing improvement in forest practices, notwithstanding some relatively minor differences between them. Both need revision from time to time as research knowledge increases and experience with their use develops.

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