Economic analysis of a target diameter harvesting system in radiata pine

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Abstract

Target diameter harvesting (TDH) is a single-tree selection system where harvesting takes place periodically, and all stems above a minimum target diameter at breast height (DBH) are removed. This report analyses economic performance of 10 years of TDH harvesting in a radiata pine forest, compared with conventional clearfell systems. Roading costs, wind risk and cashflow profiles are also discussed. Results show that TDH is able to provide similar economic returns to clearfelling for up to five TDH harvests. There is a small opportunity cost that increases with increasing numbers of TDH harvests. Land expectation value of a TDH regime is most sensitive to the discount rate, log prices and log yield. Harvesting costs and transport costs have less influence, and changes in roading costs have very little effect. There is potential for TDH to have ecosystem services benefits, but this was not explored in this study.

Introduction

New Zealand forestry manages radiata pine *(Pinus radiata)* almost exclusively on a clearfell silvicultural system. Elsewhere in the world, alternative harvesting systems such as single-tree selection, patch cutting, or group selection systems are quite frequently used, either because of biological constraints, environmental constraints or to maintain other benefits and services provided by the forest system. This research looks at an alternative single-tree selection harvesting system being implemented in a radiata pine plantation in New Zealand's Canterbury foothills.

TDH is a single-tree selection system where harvesting takes place periodically, and all stems above a minimum target DBH are removed. The rationale for using a TDH system in preference to a clearfell system is in two parts. First, by harvesting the large trees whose value increment is small in proportion to their current standing value the percentage value growth of the residual stand is increased. Secondly, harvesting under a TDH system extends the stand rotation and clearfelling is delayed or avoided altogether, which maintains non-timber benefits of the forest and mitigates any undesirable environmental effects of clearfell harvesting.

There have been very few instances of single-tree harvesting in New Zealand radiata pine (see Anon. (1956) for an example) and currently just one involving TDH – Woodside Forest in Canterbury. When considering TDH in radiata pine plantations the first question is one of economics: how do returns compare with a conventional clearfell system? Answering this question will allow forest owners to make clear decisions around the benefits and trade-offs associated with choosing to manage under a TDH system or a clearfell harvest system.

This report analyses 10 years of TDH harvesting in Woodside Forest, a 30 hectare radiata pine plantation. Economic performance is compared with conventional clearfell systems, and differences are reported in terms of land expectation value (LEV). Roading costs, wind risk, and cashflow profiles are also discussed.

Methods

Study site

The study site for this research is Woodside Forest in the Canterbury foothills. The forest comprises approximately 30 hectares of radiata pine established in small stands between 1973 and 1995. Mean annual rainfall is 1,200 millimetres, mean altitude is 450 metres and snowfalls in winter are common. All silvicultural operations are managed by owners Dr John and Rosalie Wardle. Stands were established at 1,500 stems per hectare and pruned in three variable height lifts to 6.5 metres. Stands were waste thinned to a target final crop stocking of 500 stems per hectare.

The decision to selectively harvest using TDH was made as the stands approached harvest age; the forest owners observed a wide range of diameters in these harvest-ready stands and were concerned that many stems would not yield valuable large-diameter logs. A DBH limit of 60 centimetres was selected based on the optimal tree size for producing sawlogs and peeler logs. The harvest cycle for each stand is two years, although harvesting takes place in the estate every year. The forest owner personally selects the stems for harvest, based on the diameter limit as well as the condition and competitive status of the residual stems. All harvesting is carried out by an external contractor with a two-man crew. Stems are directionally felled, extracted with a small skidder, manually processed, and loaded with self-loading trucks.

Diameter measurements were available from six permanent sample plots located in five stands and measured from 2002 to 2012. Data were analysed for the three oldest stands (established 1974, 1975 and 1976) as they had had the most TDH operations and the data were most representative of the forest.

Using growth increments between permanent sample plot measurements and a seasonal growth distribution, the data were adjusted to give a full set of diameter records at each harvest time for each stand. Stands were cruised for stem quality in 2012 and these data, combined with the diameter dataset, were used to generate per hectare yield estimates for each of the permanent sample plots at each TDH using YTGen (Interpine, 2013). Two yields were calculated for every TDH year: 1) a potential clearfell yield assuming all stems were removed: and 2) a residual crop yield from the remaining standing crop stems after TDH that year. The difference between these two yields served as an estimate of TDH yield for that plot. Heights of trees still standing were measured, while those of harvested stems were estimated using a combination of stand-specific height-diameter relationships and site-specific height-age curves.

Discounted cash flow analysis was used to compare regimes with different numbers of TDHs followed by a final clearfell. It was necessary to include the value of the final clearfell as this represents the value of the standing crop after all TDH is complete. All costs prior to the first TDH were assumed to be identical across all regimes, with roading costs incurred in full the year prior to the first harvest. Harvest costs were assumed to be 25% higher for TDHs, based on discussion with the forest owner and harvest contractor. LEV was used as the economic indicator because regimes had different rotation lengths depending on the extent of TDH. For each stand, LEV was calculated for every regime, which revealed the impact on investment returns of choosing to TDH or clearfell. A real pre-tax discount rate of 7% was used in the analysis.

Results

Investment analysis

All three stands, with differing numbers of TDHs, show similar trends (Figure 1):

1. A maximum LEV achieved at age 30 to 31;
2. A declining LEV with increasing numbers of TDHs and a delayed clearfelling.

The decline in LEV with increasing TDHs shows that there is an opportunity cost associated with using TDH to spread forest revenues over time and delay the final clearfell.

The high range in LEV between stands (Figure 1) is likely to be a function of site quality exacerbated by the fact that two of the three stands are represented by a single plot. In the context of this study, the range in LEV value between stands is not important; it is the change in LEV within stands with different numbers of TDHs that is of interest. When compared with actual stand revenues received from each TDH (data supplied by the forest owner), the revenues estimated from the plots are all higher. This is consistent with the authors' field observations that all plots are in more productive parts of the stand with excellent harvest access.

Although LEV declines in each TDH regime as the final clearfell is delayed to older ages, the revenue from TDHs may reduce the rate of LEV decline when compared with LEV versus age for a clearfell only regime. To investigate this, LEVs for different clearfell ages in the 1974 stand were estimated using the radiata pine calculator (Maclaren & Knowles, 2005). These yields were used with the same clearfell cost assumptions used to value the standing crop

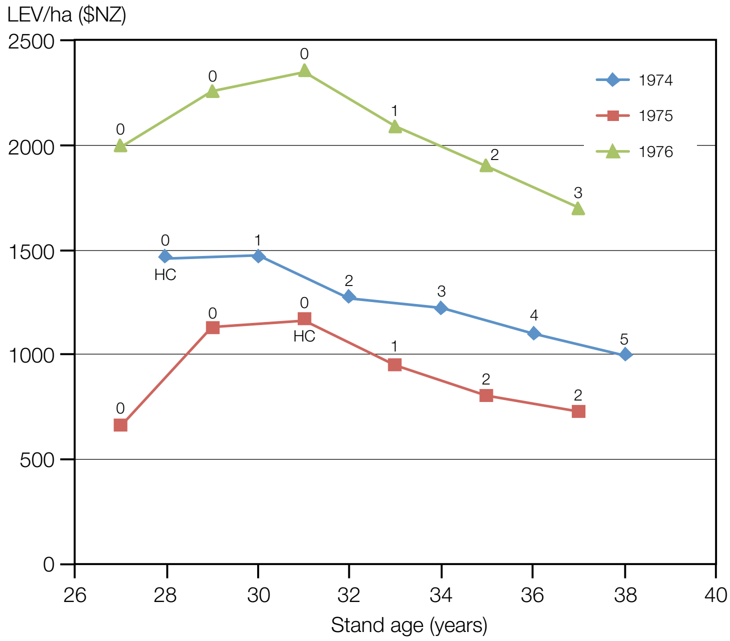

Figure 1: LEV (NZ$/ha) for three stands with differing TDH regimes. Regimes are described by numbers of TDH harvests prior to clearfelling at a specified stand age. Numbers of TDH harvests are shown by the number adjoining each data point. "HC" shows the stand age at which TDH commences. LEV is calculated for each regime independently using costs and revenues from all prior TDH combined with the value of the standing crop at the age it is clearfelled. Establishment year for each of the three stands is shown in the legend

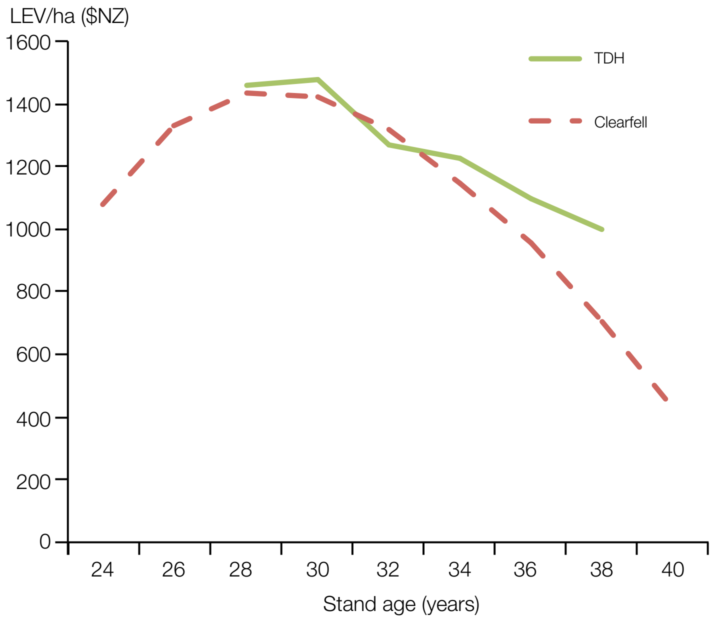

Figure 2: Comparing LEV of the 1974 stand under TDH and clearfell regimes

under TDH. These LEVs were then compared with the LEVs for the TDH regimes in the 1974 stand for clearfelling ages ranging from 28 to 40 (Figure 2).

Starting at stand age 28 years, the LEV value for clearfell harvesting initially tracks very closely to 1974 LEV under TDH, but begins to diverge from the TDH

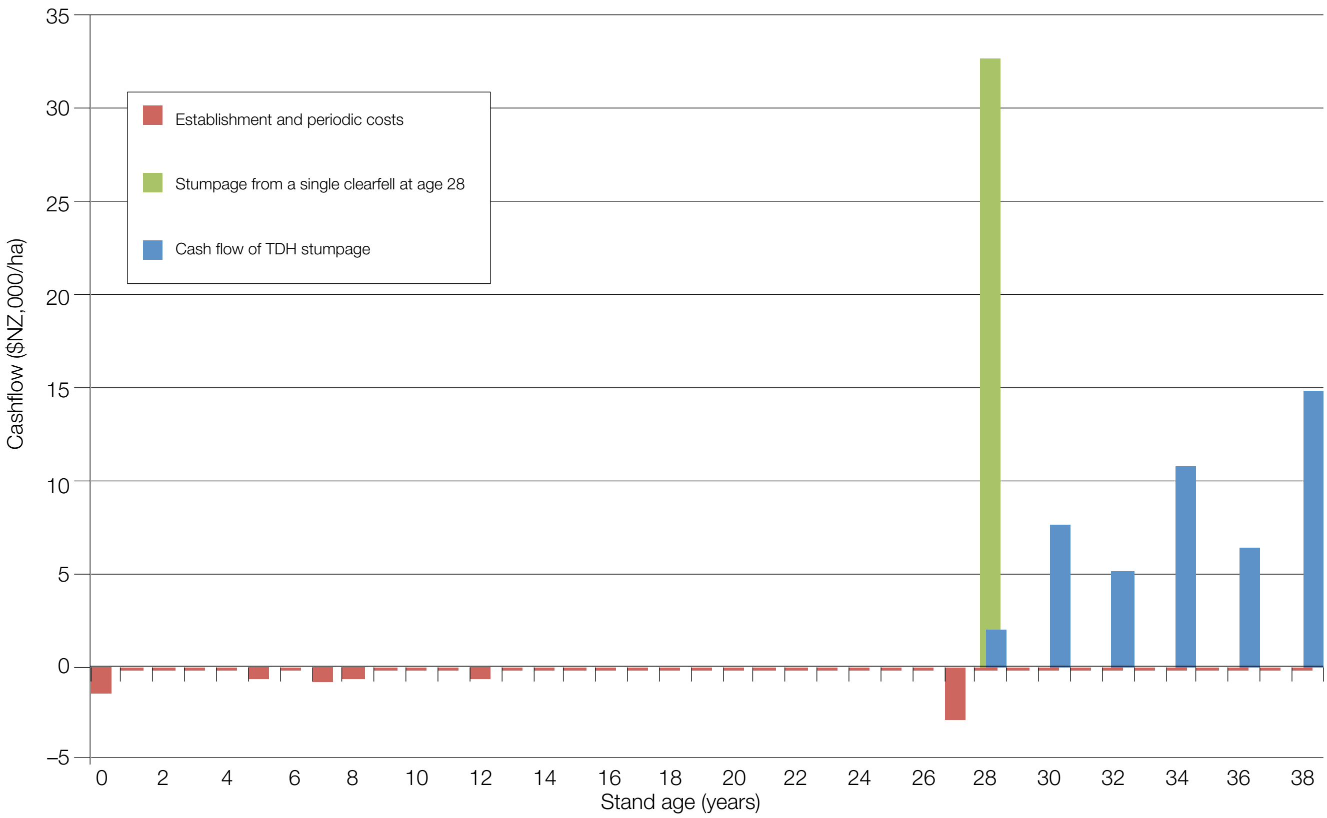

Figure 3: The cash flow profile predicted from permanent sample plots in the 1974 stand with under the base case regime with five TDH partial harvests compared with a single clearfell. Note that the periodic (annual) cost of $50 is almost indistinguishable

curve beyond age 34. From an economic perspective, there appears to be little difference between choosing to clearfell or TDH for the first six years. This is a logical result; for example, after just one TDH most of the value contributing to the LEV is in the value of the residual standing forest. As the number of TDHs increases, the impact of their revenue on the LEV of the investment will be greater. The impact of the value of the residual standing forest will decrease as it is delayed to older ages, due to the time value of money. For a regime with many TDH operations, and with clearfelling postponed for several decades, the discounted value of the standing crop at time of clearfelling will tend toward zero since the clearfelling: 1) occurs many years in the future: and 2) may involve a relatively small residual volume.

Cashflow profile

One of the potential benefits of TDH that is not considered in discounted cash flow analysis is the provision of more frequent cashflow to the forest owner. TDH has the potential to provide ongoing, regular cashflow as opposed to large, irregular returns from clearfelling, which can incur large taxation liabilities. Furthermore, the owner has the flexibility to change the stem selection constraints to increase or decrease harvest revenues depending on cash flow requirements. Figure 3 highlights the differences between clearfell and TDH in terms of cash flow; a large single revenue versus a smaller biennial revenue stream that continues over 10 years. The ability to spread forest revenues using TDH may be particularly appealing to forest owners with few age classes (as is common in farm forestry), as it presents an opportunity to bridge the gap between clearfell revenues, providing continual forestry returns.

Roading costs

The cost of roading is often put forward as a barrier to TDH or other non-clearfell harvesting regimes in radiata pine forests. This is because TDH requires a similar roading network to clearfelling prior to the first harvest taking place, but forest revenues are spread out under TDH which can extend the payback period. Analysis of the data from this study does not support this. LEVs (Figure 1) were calculated including a roading cost of $2,500 per hectare (assuming a construction and maintenance cost of $100,000 per kilometre of road and a roading density of 40 hectares per kilometre) incurred in the year prior to the first TDH. A sensitivity analysis (Figure 4) shows that overall economic performance is only weakly sensitive to changes in this roading cost and far more likely to be affected by log prices, log yield and discount rate.

Despite a low impact on investment economic performance, the cost of roading prior to TDH harvesting still has the potential to cause cashflow problems to the forest owner. However, assuming the forest is a profitable investment, borrowing capital to establish a roading network will not have a major impact on investment returns, although it may delay the onset of positive cash flow from TDH.

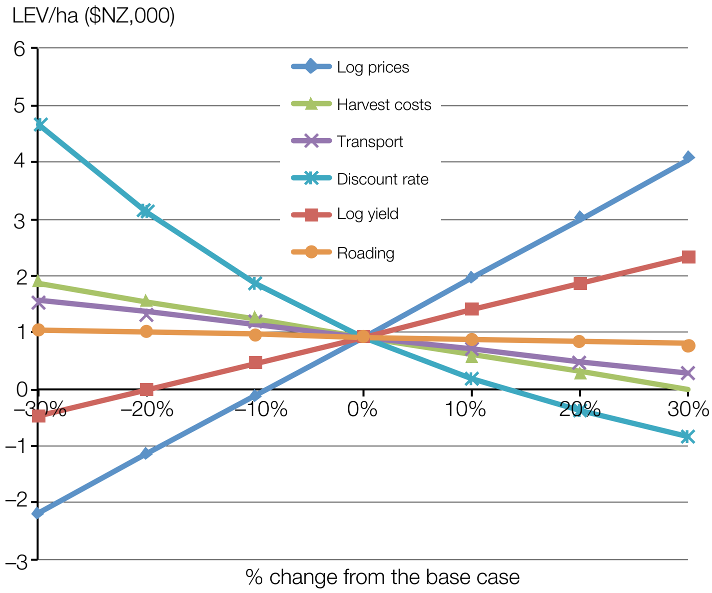

Figure 4: Sensitivity analyses of the 1974 stand LEV/ha with five TDH operations

Wind

Increased windthrow risk is another perceived disadvantage of managing radiata pine under a TDH system. It is widely accepted that forests are more likely to suffer large-scale windthrow losses in the years immediately following a thinning operation (Somerville, 1980 & 1989). But is this phenomenon applicable to TDH?

Thinning operations in a clearfell system are usually done from below, removing smaller low quality trees. The result is that the remaining crop is widely spaced with a high height:DBH (h:d) ratio, both of which are factors that can increase forest susceptibility to wind damage (Bergeron, et al; Mitchell, 2009; Mason, W., 2002; Somerville, 1980).

Under a TDH system, harvests effectively thin from above. The degree to which the forest spacing is increased can be controlled by the selection intensity of each TDH. At Woodside Forest, approximately 30 trees are removed per hectare per year (Wardle, pers. comm.) This is far fewer trees than are typically removed in a thinning operation in a conventional clearfelling system. These are key differences, and provide reason enough to at least question the notion that TDH will increase susceptibility of radiata pine forests to wind damage. In locations where windthrow is a regular occurrence anyway, TDH provides the opportunity to salvage material as part of scheduled operations.

If a final clearfell is avoided altogether, the forest structure will tend toward a mixed age 'irregular' forest as future crop trees become established under the partial canopy. While there is a lack of definitive research on the effects of forest structure on wind susceptibility, it is well documented that irregular forest structures have lower h:d ratios and that this could potentially increase wind-firmness (Mason, W., 2002; Schelhaas, 2008). Establishment of future crop trees under a partial canopy also has potential to reduce wind damage to younger trees which can be a significant problem for New Zealand radiata pine plantations (Mason, E.G., 2002). Shelter provided by the older trees may reduce toppling, and the root systems of naturally regenerated trees are widely believed to be more resistant to windthrow.

A visit to Woodside Forest to assess wind damage after several major wind events in 2013 provided support for the forest owners' assertion that TDH does not increase the risk of wind damage. The authors estimate that 5%–7% of the estate was windthrown, most of which was scattered as single stems or small groups. The worst areas of windthrow occurred on slopes that have had little or no TDH. Ninety per cent of the windthrow is expected to be recovered (made possible by a ready network of roads established for TDH), and the effect on forest will be similar to a heavy partial harvest.

Discussion

The quantity and nature of data available for the study was the biggest limitation in the study. A limited dataset of six plots across five stands meant that the analysis cannot represent true yields and economic values of TDH or clearfell regimes at Woodside Forest. For this reason, it is not very useful to quantify the opportunity cost associated with TDH in this study since the absolute values are probably incorrect. However, since both clearfell and TDH LEV's are calculated from the same data source, comparisons between the two are valid. The length of time covered in the study was restricted to 12 years of TDH, with five partial cuts and

a final assumed clearfell value, as this was the extent of TDH management at Woodside Forest at the time the study was conducted.

The regime analysed in this study was dictated by what the forest owner has implemented and is not necessarily optimal. The diameter limit of 60 centimetres was based on the optimum size for the mills the owner intended to supply, rather than any growth modelling or economic optimisation. Similarly, the two-year harvest cycle was chosen based on cash requirements and estate structure. A change in the diameter limit could have a significant effect on the LEV of the regime as it is likely to change the age at which harvesting begins. Earlier revenue streams would not only have an impact on LEV but could be more attractive to forest owners as there is a shorter wait between capital investment and positive cash flow. Changes in the harvest cycle will impact the volume extracted per harvest, which has the potential to affect harvest rates and LEV, as well as impact on the cash flow profile.

The economic calculations do not account for the fact that the forest owners are highly experienced farm foresters and ecologists who manage their crop on a day-to-day basis. Continual control of blackberry and gorse, grazing regimes, and an ability to personally undertake minor forest operations have surely played a major part in the success of TDH at Woodside Forest. Although this is unlikely to have had a significant impact on the economics of the first rotation (for the first rotation, the only necessary added management is the stem selection process), the success of the future crop trees under partial canopy may depend on regular stand management that provides the right environment for establishment as well as ongoing pruning and thinning.

The analysis in this report focuses solely on economics, and does not take into account one of the primary advantages of partial harvesting – the indefinite preservation of non-timber benefits such as water quality, biodiversity values, soil stabilisation, aesthetic appeal and carbon storage. The LEVs only include growing costs and revenues from timber products. Economic values placed on non-timber products and services are usually non-market estimates and are not realised in actual financial returns (Klemperer, 1996). This leads to economically optimal regimes that place minimal importance on non-timber benefits and usually then leads to their loss through clearfell harvesting systems. However, as social demands continue to raise the environmental and ecological standards expected of the forest industry, harvest and management techniques such as TDH that maintain non-timber values while still providing an acceptable economic return could potentially become more favourable.

Further work

Further research and experiments are needed to substantiate the findings in this analysis and assess the effects of more than 10 years of TDH. Future analysis of Woodside Forest would allow analysis of how greater numbers of partial harvests affect LEV. This would also provide some preliminary assessment of the transition phase from the first rotation to the regenerating crop.

The establishment of the second rotation crop is an issue that needs to be addressed. Will natural regeneration occur sufficiently under the TDH system? If so, how will this need to be managed to ensure the structure and quality of the next crop? These questions can only be answered through the implementation of TDH and experimentation with management methods. Woodside Forest provides an opportunity to monitor this.

Conclusions

Results from Woodside Forest show that TDH is able to provide similar economic returns to clearfelling for up to five TDH harvests. There is a small opportunity cost that increases with increasing numbers of TDH harvests. Due to data limitations, no attempt was made to quantify the opportunity cost in terms of an economic loss of the investment value of stands.

The effect of revenue from TDH on LEV is small in initial harvests due to most of the stand value being retained in the standing crop. As the length of time a stand is managed under a TDH system increases, the influence on LEV of the standing crop will be smaller, and the influence of revenue from TDH will be greater.

LEV of a TDH regime is most sensitive to the discount rate, log prices and log yield. Harvesting costs and transport costs had less influence, and changes in roading costs had very little effect. There is potential for TDH to have ecosystem services benefits, but this was not explored in this study.

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