Motu Working Paper 21-04

Permanent forest investment in a climate of uncertainty

Sandra Cortés Acosta and Arthur Grimes

March 2021

Document information

Author contact details

Sandra Cortés Acosta

Motu Economic and Public Policy Research (at time of paper preparation)

Arthur Grimes

Motu Economic and Public Policy Research, and Victoria University of Wellington

arthur.grimes@motu.org.nz

Acknowledgements

We thank New Forests for commissioning and funding this project plus Catherine Leining for informative conversations at the outset of this project. We also thank Adam Daigneault for making available the detailed assumptions underlying the analysis in Monge et al. (2018) and for permitting us to use these assumptions to underpin our work.

Disclaimer

The authors bear full and sole responsibility for the contents of the paper.

Motu Economic and Public Policy Research

PO Box 24390 info@motu.org.nz +64 4 939 4250

Wellington www.motu.org.nz

New Zealand

Abstract

Forestry investment involves long time horizons, and planting decisions must be made amidst a range of uncertainties. In the context of these uncertainties, we analyse investment decisions that involve plantation of existing grazing land in exotic versus indigenous forest species. We discuss how investment irreversibility coupled with uncertainty (and the ability to learn about the uncertain factors prior to making an investment decision) impact on the forestry investment decision. The twin features of investment irreversibility plus uncertainty are particularly relevant in relation to the new “permanent forest” category under New Zealand’s Climate Change Response (Emissions Trading Reform) Amendment Act 2020. We provide background to the new regime by reviewing the permanent forest category, and we also review relevant investment theories. The issues facing investors are illustrated with reference to a recent study that explored the role of climate uncertainty for forestry investment decisions.

JEL codes

D81, H23, Q54

Keywords

Permanent forest, indigenous forest, emissions trading scheme, climate change, uncertainty

Summary haiku

Forest investment

Uncertain like the weather

It may pay to wait.

Table of Contents

1 INTRODUCTION 5

2 BACKGROUND CONSIDERATIONS 6

2.1 Permanent Forest 6

2.2 Determinants of investment: Standard approach 7

2.3 Additional reasons for forest investment 8

2.4 The role of uncertainty and timing on investment decisions 8

2.5 Uncertainties relevant to permanent forest 12

2.6 Portfolio considerations 13

3 AN ILLUSTRATIVE MODEL 14

3.1 Scenario Set 1: Tōtara log price risk 15

3.2 Scenario set 2: Permanent versus standard forest 17

4 CONCLUSIONS 19

5 APPENDIX: MODEL PARAMETERS 21

6 REFERENCES 24

1 INTRODUCTION

Forestry investment involves long time horizons, and planting decisions must be made amidst a range of uncertainties. The uncertainties include the future paths for log prices, carbon prices, costs and the potential for regulatory changes. Uncertainty increases with the length of the investment time horizon so a commercial decision to invest in indigenous forest species,[1] which have long harvest rotation periods, is likely to embody greater uncertainties than is a decision to invest in exotic forest species (especially *pinus radiata*). In addition, forestry investments (which are costly to reverse) on existing grazing land are more affected by uncertainty than is a continuation of grazing because the investment decision is difficult to unwind if the outcomes (for the uncertain variables) turn out to be unfavourable.

Our focus is on the choice for an investor regarding decisions that involve active plantation of existing grazing land in exotic versus indigenous forest species. We analyse a scenario in which landowners register their land under the New Zealand Emissions Trading Scheme (NZ ETS) so that carbon credits from planting trees – known as New Zealand Units (NZUs) – become part of the expected cash flows. (We also discuss the choice of whether or not to plant a forest on existing grazing land but that choice is not our central focus here.)

Traditional approaches to investment theory, which do not take account of the irreversibility of investment in a context in which the investor can learn about relevant uncertainties, provide inadequate guides to forestry investment. They become increasingly inadequate as uncertainty increases and/or as the investment time horizon lengthens. In a New Zealand context, this means that these frameworks are particularly inadequate for investors who may be considering an investment into a *permanent forest*. Permanent forest is a category introduced through the Climate Change Response (Zero Carbon) Amendment Act 2019 ("the Zero Carbon Act"). A permanent forest is restricted from deforestation and clear-fell harvesting for at least 50 years; additionally, the forest land under this activity must remain registered in the NZ ETS for at least 50 years as permanent forestry and is subject to further limitations thereafter (Cortés Acosta et al., 2020).

In this non-technical note, we discuss how investment irreversibility coupled with uncertainty (and the ability to learn about the uncertain factors prior to making an investment decision) impact on the forestry investment decision. The purpose is to provide potential investors and policy-makers with an appropriate way of thinking about investment in exotic or indigenous

[1] The Climate Change Response (Emissions Trading Reform) Amendment Act 2020 defines indigenous forest species as forest species that occur naturally or have arrived in New Zealand without human assistance.

forestry (and, particularly, investment in permanent forest) rather than to provide a technical treatment of the investment decision.

We initially provide some background by reviewing the new permanent forest category for forest plantations (either indigenous or exotic forest species) in the context of the Zero Carbon Act. We then review traditional investment approaches followed by discussion of the importance of uncertainty and related factors in altering the optimal approach to investment decisions when the timing of the initial investment (i.e. initial land preparation and planting) is flexible (as is often the case for forestry). We illustrate the issues with reference to a recent study that explored the role of climate uncertainty for forestry investment decisions. We use this example to show how the optimal forestry investment choice under conditions of uncertainty may differ from that under a regime in which investment timing is inflexible and the future is treated as either being certain or as if all the relevant probabilities are known. In our analysis and conclusions, we also discuss how non-market factors may impinge on the investment decision.

2 BACKGROUND CONSIDERATIONS

2.1 Permanent Forest

Under the Climate Change Response (Emissions Trading Reform) Amendment Act, passed in June 2020, post-1989 forest land registered in the NZ ETS from 1 January 2023 will be categorised as either permanent forest or standard forest. Standard forests will account for carbon sequestration using an averaging method while permanent forests will account for sequestration using stock-change accounting. The latter accounting method enables the forest owner to account for a greater degree of carbon sequestration than is possible using the averaging approach for standard forests and hence enables the forest owner to earn a greater number of NZUs (Cortés Acosta et al., 2020). These carbon credits can be traded so offering investors a source of income prior to other income streams (e.g. from selective logging) being earned.

The counter-balance to this beneficial ability to earn NZUs is that while permanent forests can be selectively logged (subject to stipulated constraints) they are restricted from clear-fell harvesting for at least 50 years and will have to remain in the NZ ETS as a permanent forest for those 50 years. After that period, the investor will have the option to: (i) extend participation for a further 25 years; (ii) transition to be a standard forest, but this would involve repayment of the differential amount of NZUs gained by virtue of being a permanent rather than a standard forest over the first 50 years; or (iii) exiting the scheme entirely and repaying all NZUs earned since the forest was registered.

Thus, under the new legislation, a forestry investor can choose to operate under the permanent forest regime with greater potential returns to carbon sequestration but with stronger lock-in constraints. The lock-in constraints are primarily regulatory. In addition, investors in indigenous forest species face longer rotation periods (if they choose to log at all) than do those who plant exotic species. (As discussed later, investors in indigenous forest species may choose not to harvest, instead gaining a non-monetary aesthetic return from planting an indigenous forest.) In the following, we analyse how an investor may wish to approach this trade-off when choosing the appropriate regime.

2.2 Determinants of investment: Standard approach

Traditionally, investment theory has assumed that investors in commercial operations seek to maximise their expected profit, subject to some level of risk that they are prepared to take. Under this approach, an investor will make judgements regarding their expected gross returns, their expected costs and the risk associated with the investment. They will also make judgements of these factors for alternative investments that they might invest in, and then choose the investment with the highest expected risk-adjusted net rate of return.

Expected returns on a forestry investment will be influenced by expected costs, the yield in terms of number of logs, and the expected price for logs when the forest is cut. If the investor registers their forest in the ETS (as we henceforth assume), the quantity and price of carbon credits that the investor may earn will also form an expected stream of returns. Expected costs include the costs of establishing the forest, costs of forest management, costs of harvesting and transporting logs, and interest costs. Costs and returns may vary across tree types and so the expected costs and returns are specific to each type of tree that the investor may consider planting.

Interest costs over the life of the investment will depend on the length of time until trees are harvested, so length of harvesting rotation is another important aspect of an investment decision. The way that an individual investor values future returns relative to the present will affect the decision. For instance, if the investor is very patient they may prefer a tree type with a longer rotation period than will an investor who is more impatient.

Risks surrounding the investment in each tree type are relevant. Risk includes variability in log prices, costs (including operational and interest costs), and ‘physical’ risks such as disease, drought, fire, etc. (The investor also faces risk when making decisions about trading carbon credits, but conceptually this risk is distinct from the risks incurred in the decision to plant a forest.)

If risk is fully diversifiable, then the appropriate measure of risk reflects how the net return varies in relation to overall market returns (i.e. 'the market portfolio'); if the risk is not fully diversifiable then the volatility of the forest returns also represents a source of risk. Another source of risk is regulatory risk, in which the laws and regulations affecting the forest owner may change over the life of the forest. In practice, given the numerous changes in legislation that have occurred with respect to the treatment of forestry in the ETS, this source of risk should not be under-estimated.

If forestry is not the only option for investment on a particular block of land (e.g. if it could also be used for sheep and beef) then the same assessments have to be made about gross returns, costs, timing and risk as is undertaken for the forestry alternatives. A decision can then be made as to whether to invest in forestry (and, if so, in which type of forestry) or in some other activity on that land. This decision, however, is not our central focus.

2.3 Additional reasons for forest investment

As well as commercial returns, investors may have other objectives that affect the decision to invest in forestry. One reason, for instance, may be to prevent erosion on a particular block of land.

A more intangible, but no less important, reason for investing is that the investor may value establishment of a particular type of forest – most likely of indigenous forest species – on the land. This preference may be due to cultural or aesthetic reasons. In this situation a non-market return can be added to the market returns referred to above to arrive at a gross return on the investment. The non-market return is the value that the investor places on having a particular type of forest on the land, over and above any commercial value of the forest.

2.4 The role of uncertainty and timing on investment decisions

The discussion above has been couched in terms of investing in an environment in which there is risk. *Risk* refers to a situation in which future outcomes are variable, but the probability distribution for those outcomes is known. For instance, the outcome for the toss of a fair coin prior to the toss is unknown but it is known that the probability of each of Heads and Tails is 50%.

In practice, many decisions are made under conditions of uncertainty rather than risk. *Uncertainty* refers to a situation in which we do not know the distribution regarding future outcomes, and we may not even know the full range of future outcomes that is possible. For instance, a person planting a forest in 1985 would probably not have contemplated an ETS scheme being in operation in 2015.

The discussion above has also been couched in terms of a once-only decision on investing – i.e. where the investment decision is being made now, with no option to delay the decision to another time. In practice, forestry planting decisions can generally be delayed for one or more years.

Modern investment theory has been extended to incorporate the effects of timing choices and the roles of both risk and uncertainty on optimal investment decisions (Dixit & Pindyck, 1994; Guthrie, 2009). This modern theory is known in finance and economics as 'real options theory', and it has a close counterpart – 'adaptive management' – in the environmental and related fields. These approaches are relevant for optimal decision-making when four features are present in relation to the investment decision:

(i) The path of future returns (and costs) is subject to risk or uncertainty;
(ii) One can learn over time about how these returns and costs evolve;
(iii) Investment decisions can be made now or later; and
(iv) Investments are (at least partly) irreversible once made.

All four of these features are present for forestry investments. Consequently, analyses of optimal forestry investments and harvesting decisions are now commonly modelled using real options theory (Thomson, 1992; Manley & Niquidet, 2010; Tee et al., 2012; Manley, 2013).

An important insight from these theories for investors is that – in the presence of the four features listed above – investments should not be made on a conventional risk-adjusted present discounted value (pdv) basis (i.e. where gross returns and costs are valued, and discounted, over time subject to a standard risk premium). The reason for not following this 'standard' approach stems from the irreversibility of the investment, coupled with the ability to delay investment until more is learned about the path of returns. The irreversibility plus the ability to learn about the environment over time often leads to an optimal strategy of waiting to invest rather than investing immediately. A positive investment decision, in these circumstances, generally requires that the expected rate of return must exceed a higher hurdle rate than would be required under a more simplistic (pdv) approach.

To illustrate why waiting in these circumstances may be optimal, consider a situation in which a gambler is at a roulette table. The gambler does not know whether the table is rigged to favour a particular category (colour or number) but suspects that this is a possibility. From the gambler's point of view, an initial bet on any category is equally likely to be successful. However, by delaying their first bet, possibly for a number of spins of the wheel, they can make a better judgement as to whether the table does favour a particular category. By delaying their bet and learning about the odds, they can subsequently enjoy better odds than if they were to make a bet at the opening.

The same reasoning is relevant for a forestry investor (and investors in many other forms of irreversible investment). Many of the factors that influence the final profit arising from the planting of a forest are subject to risks or uncertainties as to their evolution over the life of the forest.

The price of carbon credits is one profit determinant which is subject to risk (and/or uncertainty). The risks to these prices may come from domestic market forces (e.g. changes in the quantity of carbon credits demanded from industry) or from international forces (especially if there is some linkage to credits in other countries).

A source of uncertainty is the possibility of changes to government laws and regulations that affect the quantity or price of carbon credits. Each new government has implemented changes to the ETS system (including its treatment of forestry) since the advent of New Zealand's first ETS in 2008 (Ministry of Agriculture and Forestry, 2011). The release of the Climate Change Commission's Draft Advice for Consultation in January 2020[2] is a recent example in which investors may have a newly heightened reason to expect changes in the operation of the ETS system given that document's emphasis on planting indigenous versus exotic forest species in order to achieve New Zealand's climate goals. It is reasonable for investors to anticipate further changes to aspects of the ETS that will affect future quantities or prices of carbon credits, but without a clear picture of what those changes might be.

In this light, consider a potential forestry investor whose prospective investment is just profitable on the basis of current expectations for forestry prices, costs and carbon credits. Planting the forest represents an irreversible investment (or, at least, an investment for which there would be major costs borne if the investment was to be reversed). For expositional purposes, assume that there is a 50:50 chance that the carbon price might rise or fall in the following year relative to initial expectations. If the price were to rise, the forestry investment

[2] https://ccc-production-media.s3.ap-southeast-2.amazonaws.com/public/evidence/advice-report-DRAFT-1ST-FEB/ADVICE/CCC-ADVICE-TO-GOVT-31-JAN-2021-pdf.pdf

would become even more profitable. Conversely, if the price were to fall, the investment would no longer be profitable, but the costs of reversing the investment would preclude a reversal. The investor could reduce the risk of an adverse outcome by delaying their initial investment decision for a year to see if the carbon price rises or falls over that time. Naturally, the same logic follows in subsequent years, so an investor will require a substantial positive expected return to the investment prior to making an irreversible investment by planting the forest.

The same logic follows for a decision regarding premature felling of a forest once planted, even if, on current projections, it will not be profitable. The felling of a forest incurs irrevocable costs. By delaying the decision to fell, the forest owner retains the possibility that prices will move in their favour so restoring the profitability of their investment. This logic implies that the felling of a forest (prior to expected harvest time) will be rare.

Combined, these two influences mean that a hurdle rate that embodies a substantial premium over the risk-free return will be set by a rational forest investor. The prospective return will have to exceed this hurdle rate prior to a forest being planted. It will also be unusual to see a forest felled well before projected harvest time. As uncertainty regarding prices, costs and the possibility of government-induced changes to the regime increase, these effects are magnified. The longer is the forest rotation, the greater is the degree of uncertainty surrounding both log and carbon prices[3] and, to a lesser extent, also surrounding costs. Thus planting a forest in tree types with longer rotation periods will (other things being equal) be subject to greater uncertainty. Choosing to plant a forest through the option of the permanent forest category is equivalent to adopting a long rotation period, so increasing uncertainty about the quantity and price of carbon credits (and also of other costs and returns).

It is worth noting that once a forest is planted, a greater degree of uncertainty (that results in greater price volatility) can act to increase prospective returns provided the timing of harvesting is flexible (Manley, 2013). The reason for this is that the forester can choose to delay harvesting when log and/or carbon prices are adverse and wait to see if prices improve at which time the harvest decision can be taken. While this factor can increase returns once planting has taken place, it does not offset the benefits of waiting prior to the planting decision until such time as a high enough prospective rate of return (that exceeds the hurdle rate) is reached.

[3] Price volatility increases with the length of the time horizon if prices are non-stationary in statistical terms (i.e. if they do not revert to some expected value over time). Manley (2013) reports evidence supporting non-stationarity of prices and so models the harvesting decision under conditions in which both log and carbon prices are non-stationary.

2.5 Uncertainties relevant to permanent forest

The length and nature of a forestry investment means that it is subject to many risks and uncertainties that can affect future payoffs. A non-exhaustive list includes the following, for which the uncertainties relate to both short-term and long-term potential outcomes:

2.5.1 Market force uncertainties

- Uncertainties regarding timber prices, both in absolute terms and in relative terms (e.g. the price of indigenous logs versus exotic logs);
- Costs of forest management;
- Uncertainties relating to prices and costs of non-forestry activities that could be conducted on the same land (e.g. sheep and beef);
- Uncertainties regarding interest costs and access to finance;
- Uncertainties relating to the cost and availability of insurance;
- Uncertainties regarding carbon prices.

2.5.2 Physical uncertainties

- Uncertainties regarding weather events (storms, etc) and long-term climate changes that affect either tree growth or damage;
- Other uncertainties relating to the rate of tree growth or survival, such as disease.

2.5.3 Personal uncertainties

- Uncertainties regarding future ownership intentions by oneself or one's successors. (Note that this factor could be a 'standard' uncertainty in that it may reduce the wish for lock-in or it could have the opposite effect if the intention is to bind the owner's successors to a chosen path to reflect the current owner's own ethical judgements.)

2.5.4 *Regulatory uncertainties*[4]

- Uncertainties regarding the degree to which any existing provision (or property right) will be grandfathered (in full or in part) or replaced by new provisions;
- Uncertainties regarding the number of carbon credits that may be allocated for certain types of forests and management approaches (either due to scientific reappraisal or political economy reasons);
- Uncertainties surrounding the ability for future harvest of indigenous forest species, given a track record of past changes in harvesting rights for privately owned indigenous forest species;

[4] The term 'regulatory uncertainties' is taken here to include legislative uncertainties.

- Uncertainties relating to the granting of exemptions for the need to purchase carbon credits for alternative land uses (especially for sheep and beef);
- Uncertainties relating to regulatory changes in the treatment of minimum canopy cover (especially for permanent forests);
- Uncertainties relating to penalties for cutting forest ahead of time (especially for permanent forest);
- Uncertainties surrounding the relative treatment of indigenous versus exotic forest species with respect to carbon credits or other subsidies (e.g. an amenity subsidy for indigenous forest species);
- Uncertainties surrounding the possible introduction of an entirely new legislated forestry option that is superior to either standard or permanent forest categories.

Almost all the uncertainties listed above (with the exception of the wish to bind one's successors) raises the bar for entry into forestry relative to a more flexible land use such as sheep and beef, since the latter can always be converted to forestry in future at similar cost to current conversion while retaining flexibility over whether or not to do so. The uncertainties also raise the bar (i.e. the required expected return) to locking in a forest for a longer period (e.g. through permanent and/or indigenous forest) than is required for a standard exotic forest.

2.6 Portfolio considerations

Portfolio considerations may provide a partial counter-weight to the lock-in disadvantage. Consider, for instance, a farmer who expects to be exposed to the need to purchase carbon credits to cover emissions from their sheep and beef farm. In the absence of a perfectly operating futures market in carbon credits, the farmer bears a risk relating to future price changes in carbon credits. The farmer can, however, obtain a natural hedge to this exposure by planting a forest on part of their land that earns carbon credits. In this situation, if the carbon price were to increase the farmer bears a greater liability through their sheep and beef operation but has an offsetting asset that increases in value through their forestry plantings. This portfolio benefit to the farmer of planting some land in forest is unlikely to extend to choosing a long horizon alternative (e.g. a slow growing tree type or permanent forest) unless the farmer also wishes to lock in a very long term commitment to sheep and beef farming. The portfolio benefit is therefore likely to favour some planting of forest, but mainly through planting a shorter rotation option such as *pinus radiata*.

3 AN ILLUSTRATIVE MODEL

The value of waiting to make an investment decision when the four features listed earlier are present is illustrated through a forestry example. To recap, the four key features that underpin the analysis – and which are likely to be present when making forestry investment decisions – are as follows:

(i) The path of future returns (and costs) is subject to risk or uncertainty;

(ii) One can learn over time about how these returns and costs evolve;

(iii) Investment decisions can be made now or later; and

(iv) Investments are (at least partly) irreversible once made.

Our illustration is based on two forestry investment alternatives outlined in Monge et al. (2018). That paper examined three potential forestry planting regimes for the East Coast of the North Island of New Zealand. The three alternatives considered were:

1. Planting manuka-only.
2. Planting mānuka plus tōtara.
3. Planting manuka, tōtara and kawakawa.

We confine our attention to the first two of these planting alternatives. In each alternative, revenue is derived from mānuka honey (starting in year 4, where year 0 is the initial year of planting) and from the gathering of carbon credits. The second alternative derives additional revenues from the sale of tōtara logs. Tōtara is first planted in year 8, within the existing mānuka plantation, and tōtara harvesting begins in year 88. Mānuka honey revenues are reduced under this mānuka plus tōtara alternative relative to the mānuka-only alternative. The Appendix provides details of the assumptions underlining the two alternatives, each of which is based on the analysis in Monge et al. (2018). One additional assumption that we make relative to that analysis is that the mānuka plus tōtara alternative generates additional non-monetary amenity benefits to the owners which do not occur in the mānuka-only alternative; for instance, an iwi or local environmental group may derive (non-monetary) amenity benefits from the planting of a tōtara forest.

We calculate the pdv of net benefits (i.e. of benefits minus costs) for each alternative under different assumptions about how prices will evolve for two different sets of scenarios. Consistent with our inclusion of non-monetary benefits, we assume that the investor in this example places a high value on future benefits and so uses a low discount rate (a real rate of 1% p.a.). The choice of discount rate will affect the precise numbers in our calculations but our central message about the likely importance of waiting to invest is not affected by the specific choice of discount rate.

3.1 Scenario Set 1: Tōtara log price risk

Our focus in the first set of scenarios is on risk attached to the price of tōtara logs.[5] The analysis in Monge et al. (2018) assumed that the price of logs (and other relevant prices such as the carbon price) were subject to risk. Their approach was to calculate the pdv of the two alternatives after accounting for the probability distributions of the variables that were subject to risk. They then ranked the alternatives based on their pdv's, assuming that the investment decision was taken irrevocably at year 0.

Our approach instead concentrates on how risk may affect the decision to invest in a long-lived project where the timing of the investment is flexible. We assume a very simple form of risk: the price of tōtara logs (which initially have an expected value of $350/m^3 upon harvest) may be revised either upwards or downwards by $50/m^3 in year 9. The chance of an upward or downward revision is 50:50. Note that year 9 is the year after the initial intended planting year for tōtara.

Table 1 presents the pdv per hectare (ha), as viewed from year 0, for each of the two alternatives (mānuka-only, and mānuka plus tōtara) using different values for the tōtara log price. The first column uses the expected value for tōtara logs of $350/m^3. The second and third columns present the pdv's for log prices of $300/m^3 and $400/m^3 respectively, and the final column provides the expected value based on the third and fourth columns. Table 1 incorporates a non-monetary amenity benefit from tōtara planting of $500 per ha per annum (p.a.) from year 9 onwards. We refer to this case as 'medium amenity benefits' to differentiate it from subsequent cases.

Table 1: pdv ($s per ha) for different tōtara log prices, medium amenity benefits, as at year 0**

	Tōtara log price			Expected value with
	$350	**$300**	**$400**	**equal probability of $300 and $400**
Mānuka-only	43,825	43,825	43,825	43,825
Mānuka plus tōtara	43,340	32,043	54,638	43,341

*Assuming a non-monetary amenity benefit from tōtara planting of $500 per ha p.a. from year 9 onwards.

[5] The parameters underlying these scenarios are such that variations in the carbon price make very little difference to the choice between the two alternatives. Variations in the carbon price become relevant with a change in the parameters relating to carbon benefits considered subsequently.

In each of the cases shown in Table 1, it is assumed that the planting investment decisions are taken irrevocably at year 0, as with the analysis in Monge et al. (2018). Hence, under the mānuka plus tōtara alternative, the decision is taken in year 0 that tōtara will be planted starting in year 8. Given our stylised assumptions about when new information arrives (i.e. in year 9), it makes little difference whether we calculate the pdv's in year 0 or in year 8. To demonstrate that this is the case, Table 2 presents the pdv as viewed from year 8 for each of the two alternatives. It again incorporates a non-monetary benefit from tōtara planting of $500 per ha p.a. from year 9 onwards.

Table 2: pdv ($s per ha) for different tōtara log prices, with medium amenity benefits, as at year 8*

	Tōtara log price			Expected value with equal probability of $300 and $400
	$350	$300	$400	
Mānuka-only	46,719	46,719	46,719	46,719
Mānuka plus tōtara	46,305	34,072	58,539	46,306

*Assuming a non-monetary amenity benefit from tōtara planting of $500 per ha p.a. from year 9 onwards.

If we were to take a standard pdv approach to investment based on these numbers, the decision in year 0 (or in year 8 if we could delay the tōtara planting decision until then) would be to adopt the mānuka-only alternative since its expected value per ha exceeds that of the mānuka plus tōtara alternative. However, if we were could defer the decision of whether to plant tōtara until year 9, we would then have a signal of whether the tōtara log price will be $300/m^3 or $400/m^3 in future. From Tables 1 and 2, we see that if the price were $400 then mānuka plus tōtara becomes the preferred alternative, and planting should proceed.

This stylised example shows that when the investment decision can be delayed until after new information comes to hand then the decision may optimally change. In this case it would change from a decision (using a pure *ex ante* pdv decision basis) not to proceed with the mānuka plus tōtara alternative to one in which this alternative is adopted, but only if the price were to rise to $400 over the decision period. (It would not change if the price remained at $350 or if it fell.)

The same logic applies if the parameters are such that the initial (pdv-based) decision was to proceed with the mānuka plus tōtara alternative. Tables 3 and 4 replicate Tables 1 and 2 but instead assume a higher non-monetary benefit from tōtara planting of $510 per ha p.a. from year 9 onwards (referred to as 'high amenity benefits').

Table 3: pdv ($s per ha) for different tōtara log prices, with high amenity benefits, as at year 0*[*]

	Tōtara log price			Expected value with equal probability of $300 and $400
	$350	**$300**	**$400**	
Mānuka-only	43,825	43,825	43,825	43,825
Mānuka plus tōtara	44,032	32,735	55,330	44,033

*Assuming a non-monetary amenity benefit from tōtara planting of $510 per ha p.a. from year 9 onwards.

Table 4: pdv ($s per ha) for different tōtara log prices, with high amenity benefits, as at year 8[*]

	Tōtara log price			Expected value with equal probability of $300 and $400
	$350	**$300**	**$400**	
Mānuka-only	46,719	46,719	46,719	46,719
Mānuka plus tōtara	47,054	34,821	59,288	47,055

*Assuming a non-monetary amenity benefit from tōtara planting of $510 per ha p.a. from year 9 onwards.

With the higher non-monetary benefits accruing to tōtara plantings, the initial pdv-based decision would be to commit to the mānuka plus tōtara alternative, and this alternative would continue to be favoured at year 8 if the tōtara log price remained at $350 or rose further. However, if the investor waited until year 9 and observed a fall in the price to $300, they would not plant tōtara and would instead retain a mānuka-only forest.

This example demonstrates the advantage of waiting before committing to a long-term irrevocable investment if it is possible to learn more about how key factors will evolve in circumstances which allow the investment timing to be flexible.

3.2 Scenario set 2: Permanent versus standard forest

The analysis in Cortés Acosta et al. (2020) indicates that investors in permanent forest can claim greater carbon benefits than can investors in standard forest provided they meet the requirements of the permanent forest regime. We modify the two alternatives described in the previous set of scenarios to illustrate the investment issues that arise when considering the choice between these two regimes. To do so, we assume that if the first (mānuka-only) alternative is chosen, in part to maintain flexibility in felling, it will be invested via the standard forest regime. In contrast, the second (mānuka plus tōtara) alternative is assumed to be invested via the permanent forest regime. For simplicity (and reflecting Figures 2 and 4 of Cortés Acosta et al., 2020) we assume that the carbon credits the investor would accrue with a permanent forest are double those that could be accrued if the investment were instead made as a standard forest.

We adopt the same parameters as above except as follows. First, we assume that the non-monetary amenity benefit for tōtara is $450 per ha p.a. from year 9 onwards ('low amenity benefits'). Second, we assume that the carbon price is expected to increase from year 9 onwards (for instance, because of a scheduled policy change to take place from that year). The investor envisages that there is an equal chance of the increase being to either $20 or $50 per tonne (from the initial price of $17 per tonne). In each case it pays to register the forest in the NZ ETS and earn carbon credits, but the relative benefits of doing so differ across the two planting regimes with the higher carbon price giving greater benefit to the mānuka plus totara alternative.

Tables 5 and 6 show the pdv for each alternative under these two price paths, plus the expected value, as calculated at year 0 and year 8 respectively. When evaluated in each year, the expected value criterion favours the mānuka plus tōtara alternative, i.e. the permanent forest option. However, the mānuka-only alternative would be favoured in the case of a low carbon price increase, since the carbon benefit of permanent over standard forest to the investor is reduced with a lower carbon price.

In this set of scenarios it again pays the investor to wait until more is learned about the relevant future price path (in this case for the carbon price) before taking an irreversible decision, i.e. choosing the permanent forest option. With other parameters, the permanent forest alternative may be preferred. However, the key lesson remains: waiting may be an optimal strategy prior to taking an investment decision that is costly to reverse in circumstances where relevant information can be learned prior to locking in that decision.

Table 5: pdv ($s per ha) for different carbon price paths, low amenity benefits, as at year 0*

	$17 → $20	**$17 → $50**	**Expected value**
Mānuka-only (standard forest)	42,002	45,545	43,774
Mānuka plus tōtara (permanent forest)	40,565	47,393	43,979

*Assuming a non-monetary amenity benefit from tōtara planting of $450 per ha p.a. from year 9 onwards.

Table 6: pdv ($s per ha) for different carbon price paths, low amenity benefits, as at year 8*

	$17 → $20	$17 → $50	Expected value
Mānuka-only (standard forest)	44,874	48,711	46,793
Mānuka plus tōtara (permanent forest)	43,299	50,694	46,997

*Assuming a non-monetary amenity benefit from tōtara planting of $450 per ha p.a. from year 9 onwards.

4 CONCLUSIONS

The permanent forest regime offers investors benefits over the standard forest regime by enabling the investor to accrue greater carbon benefits (while still retaining the option of selective logging). However, the permanent forest regime incorporates significant lock-in restrictions (especially on clear-fell harvesting) that may deter investors from choosing that alternative. The lock-in restrictions are an integral part of the regime since they are designed to deter investors from clear-felling the forest once planted.

The investment decisions and choice of regime (permanent or standard forest) may be made in an environment that bears considerable risks and uncertainties. These risks and uncertainties relate to returns (e.g. carbon prices, log prices, honey prices), costs (e.g. future harvesting and roading costs) and to the regulatory environment itself. The last of these uncertainties (the regulatory environment) includes the possibility that an improved regime could be introduced in future but, once the initial regime is chosen, the investor may not be able to transition to that improved regime.

Compared with an investment criterion based simply on present discounted value (pdv), these sources of risk and uncertainty act to reduce the chance that an investor will choose initially to register their land under a regime that has significant lock-in restrictions. Thus the take-up of the permanent forest option can, in most circumstances, be expected to be less than would be predicted based on a simple pdv maximisation strategy. This is the case, as we have shown in our examples, even where the investor obtains non-monetary amenity benefits from having the land in permanent forest and uses a low discount rate.

One counter-example to this finding is where the existing investor wishes to bind their successors to a strategy of retaining the forest permanently. In this case, the penalties for departing the permanent forest regime may be sufficient to ensure that their successors do not, in future, fell the forest. Thus there is a strong incentive for an existing owner, who wishes to leave their mark on the environment permanently, to choose the permanent forest option precisely because of its lock-in features. By contrast, purely commercial investors are more likely to choose the more flexible standard forest regime despite its lesser ability to earn credits for carbon sequestration. The choice between these two regimes may therefore be driven, at least in part, by whether non-commercial considerations are strong enough to outweigh the commercial benefits of retaining flexibility for future decisions.

5 APPENDIX: MODEL PARAMETERS

Monge et al. (2018) study the implications of several sources of uncertainty on the feasibility of afforesting erodible land with indigenous forest species. The study included three afforestation alternatives to assess the profitability of the establishment of indigenous forestry on retired grazing land, using a discounted cash flow approach. The afforestation alternatives are: (i) mānuka as a monocrop, (ii) a combination of two species – mānuka and tōtara, and (iii) a combination of three species – mānuka, tōtara and kawakawa. All alternatives started with mānuka because it is a resilient crop that can offer revenues from the sale of honey and carbon sequestration. Furthermore, mānuka provides shelter for the establishment of other indigenous species, dense canopy for rain interception, and a stable rooting system for erosion control (Monge et al., 2018).

Following the information provided in their study, we replicate the cash-flow exercise from two of the three alternatives, mānuka-only, and mānuka plus tōtara, for a time horizon of 150 years. Table A1 lists the parameters considered for the analysis.[6]

Table A1. Parameters for assessing the afforestation scenarios

Parameter	Unit
Mānuka honey price	The value per kilogram of honey drops from \$35/kg to \$25/kg from year 28 onwards as honey quality drops
Tōtara log price	\$350/m^3
Carbon price	\$17 per tonne of CO_2
Planting (all species)	\$3.95 per seedling
Interplanting (under canopy)	\$9.50 per seedling initially, increasing to \$18 for 100 stems/ha under dense canopy cover after year 28
Annual management	\$65/ha/yr. For the mānuka-only alternative this cost drops to \$30/ha/yr. after year 10.
Pest control	\$35/ha/yr.
Clearing light wells	\$2.48 per sapling for totara.
Form pruning	\$1.70 per low tōtara sapling to \$2.30 per high tōtara sapling.
Roading	\$4000/ha
Tōtara log harvest	\$100/m^3
Tōtara log transport	\$33.25/m^3

[6] During the initial four years of the crop, we use the study's numbers for various other initial outlays.

Alternative 1: Mānuka-only

For establishment costs, which include planting and weed control, it was assumed that mānuka was planted from high-quality plant stock at a high stocking rate (Monge et al., 2018). Initially, annual management cost is $65 per ha p.a., dropping to $30 per ha p.a. after 10 years. Additionally, it is assumed that pest control is $35 per ha p.a.

Revenues are from honey production and carbon sequestration. Honey productivity starts at 10 kg per ha from year 4, builds to 30 kg per ha from year 6, and drops to 20 kg per ha from year 26 into perpetuity. We assume that the value per kilogram decreases from $35/kg to $25/kg from year 28 onwards reflecting quality changes. Carbon sequestration estimates are based on the look-up tables for indigenous species developed by the Ministry for Primary Industries (2017). Given that the look-up tables are until year 50, we assume the same rate of carbon sequestered after year 50. The carbon price assumed is $17 per tonne of CO_2 captured each year.

Alternative 2: Mānuka and tōtara

In this alternative, mānuka is used as a nurse crop that provides shelter to the establishment of tōtara, using the latter as a long-term high-value crop. Like the previous scenario, annual management is $65 per ha p.a. and pest control is $35 per ha p.a. Additional planting, maintenance (i.e., light well and pruning) and harvesting costs are included in the analysis. We also include a roading cost of $4,000 per ha that takes place in year 88.

We assume that tōtara is initially planted in year 8, under established mānuka at 900 plants per ha, with a cost of $9.50 per seedling. In year 28, an additional 100 plants per ha are planted, repeating this planting routine every 20 years, with a cost of $18 for 100 stems per ha.

Light wells are created to facilitate tōtara growth. Additionally, to maintain good tōtara tree form, pruning occurs between years three and nine after planting. For the additional plantings, form pruning occurs after planting between years three and eight.

We assume sustainable recoverable volumes of tōtara that increase slowly over seven selective harvests each ten years apart, starting at 100 m^3 per ha in year 88 and finishing at 107 m^3 per ha in year 148. We assume a harvesting cost of $100 per m^3 and transport costs of $33.25 per m^3.

Revenues are from honey production, carbon sequestration from mānuka and tōtara, and timber from tōtara. Honey productivity starts at 10 kg per ha from year 4, builds up to 30 kg per ha from year 6, and drops to 10 kg per ha in year 21. Carbon sequestration from mānuka is calculated by using the look-up tables for indigenous species developed by the Ministry for

Primary Industries (2017). We assume that during the transition to the subsequent tree crop, carbon sequestration falls to half of the sequestration estimated by the look-up tables over three years before mānuka is shaded out completely. We also assume mānuka revenues stop after year 21 due to shading as the canopy transitions to tōtara. Carbon sequestration from tōtara is calculated from the time the trees are planted; timber revenues start in year 88 with a tōtara log price of \$350 per m^3.

6 REFERENCES

Climate Change Response (Emissions Trading Reform) Amendment Act, Pub. L. No. 22 (2020). http://legislation.govt.nz/act/public/2020/0022/latest/LMS143384.html

Cortés Acosta, S., Grimes, A., & Leining, C. (2020). *Decision trees: Forestry in the New Zealand Emissions Trading Scheme post-2020* (Motu Working Paper 20-11). Motu Economic And Public Policy Research. http://motu-www.motu.org.nz/wpapers/20_11.pdf

Dixit, A. K., & Pindyck, R. S. (1994). *Investment Under Uncertainty*. Princeton University Press.

Guthrie, G. (2009). *Real options in theory and practice*. Oxford University Press.

Manley, B. (2013). How does real option value compare with Faustmann value in the context of the New Zealand Emissions Trading Scheme? *Forest Policy and Economics*, *30*, 14–22. https://doi.org/10.1016/j.forpol.2013.02.001

Manley, B., & Niquidet, K. (2010). What is the relevance of option pricing for forest valuation in New Zealand? *Forest Policy and Economics*, *12*(4), 299–307. https://doi.org/10.1016/j.forpol.2009.11.002

Ministry for Primary Industries. (2017). *A guide to: Carbon look-up tables for forestry in the emissions trading scheme*. https://www.mpi.govt.nz/dmsdocument/4762-a-guide-to-look-up-tables-for-forestry-in-the-emissions-trading-scheme.

Ministry of Agriculture and Forestry. (2011). *A Guide to Forestry in the Emissions Trading Scheme*. Ministry of Agriculture and Forestry. http://www.maf.govt.nz/news-resources/publications

Monge, J. J., Daigneault, A. J., Dowling, L. J., Harrison, D. R., Awatere, S., & Ausseil, A.-G. (2018). Implications of future climatic uncertainty on payments for forest ecosystem services: The case of the East Coast of New Zealand. *Ecosystem Services*, *33*, 199–212. https://doi.org/10.1016/j.ecoser.2018.04.010

Tee, J., Scarpa, R., Marsh, D., & Guthrie, G. (2012). Valuation of carbon forestry and the new zealand emissions trading scheme: A real options approach using the binomial tree method. *2012 Conference, August 18–24, 2012, Foz Do Iguacu, Brazil*.

Thomson, T. A. (1992). Optimal Forest Rotation When Stumpage Prices Follow a Diffusion Process. *Land Economics*, *68*(3), 329–342. https://doi.org/10.2307/3146380