Forest and Forest Land Valuation – How to Value Forests and Forest Land to Include Carbon Costs and Benefits

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Overview

- Forestry in the New Zealand Emissions Trading Scheme (ETS)

- The valuation problem

- Bootstrapping Real Options Analysis (BROA) using Monte Carlo Simulation (MCS):
  - Method
  - Illustrative outputs

- Conclusions

- Note – presentation based on August 2008 study completed for New Zealand Ministry of Agriculture and Forestry (MAF)

Forestry in the ETS

- Forestry covered from 1 January 2008

- **Pre-1990 forests** (exotic only, not indigenous):
  - Emission liability imposed on <u>deforestation</u> of land first planted pre-1990 → value -ve
  - No liability from <u>harvest</u> provided forest is replanted or allowed to regenerate
  - <u>Trick</u> – if deforestation occurs >8 years from harvest, liability is based on carbon in re-growth, not in previously harvested forest

- **Post-1989 forests** (exotic or indigenous) – <u>IF</u> owners of forests first planted after 1989 opt into the ETS then:
  - Tradable emission rights (New Zealand Units, NZUs) can be earned as carbon is sequestered through forest growth → value +ve
  - Emission liability is incurred upon <u>harvest</u> (or deforestation), though capped at number of NZUs previously earned → value -ve

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The Valuation Problem

- Emission pricing adds **another random state variable** to the valuation problem (NZU price/"carbon price") → not so bad if only have one log price to start with, but typically have different prices for each log grade

- Emission pricing also further highlights the importance of valuing **managerial flexibility** in forestry:
  - Harvest timing – optimal timing now reflects carbon costs/revenues as well as timber returns
  - Harvest abandonment – ongoing carbon farming a possible alternative, or harvest may become unviable
  - Conversion into alternative land use (e.g. dairying) – i.e. deforestation – conversion costs now include carbon impacts, and conversion returns also affected (e.g. by agriculture emission costs)

- Lends itself to Real Options Analysis (ROA), despite implementation difficulties, and tests the limits of Discounted Cash Flow (DCF) analysis

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Bootstrapping ROA (BROA)

- Hybrid DCF-ROA approach – "smart then dumb" – model initial forest decisions and payoffs using ROA, but model subsequent payoffs from subsequent decisions using DCF

- Using Monte Carlo Simulation means multiple random state variables and greater decision complexity can be "easily" accommodated

- Draw on ROA principles – uncertainty means irreversible decisions (e.g. harvest, or deforestation) should only be made if the decision's payoff exceeds the value of the "option to wait" that is lost when the decision is made

- Process is:
  - Posit a forest management "decision barrier" representing this option value – parameterised by variables of *a priori* unknown optimum values – and calculate forest value assuming irreversible decisions are made only if decision payoffs exceed this barrier
  - Do this for multiple simulation trials, given assumed values of the decision barrier parameters, and estimate forest value as the average value across all those trials
  - Re-run simulations for combinations of decision barrier parameters to search for the optimum forest management rule and associated value (i.e. those parameters maximising forest value), instead of trying to derive that rule and value explicitly → "bootstrapping"

- Means BROA value will approximate true value, but should be a closer approximation than DCF value

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BROA – Calibration Test

- To demonstrate the approach, its results were compared with a simple known analytical result – McDonald and Siegel (1986) investment timing problem (infinite horizon, continuous time)
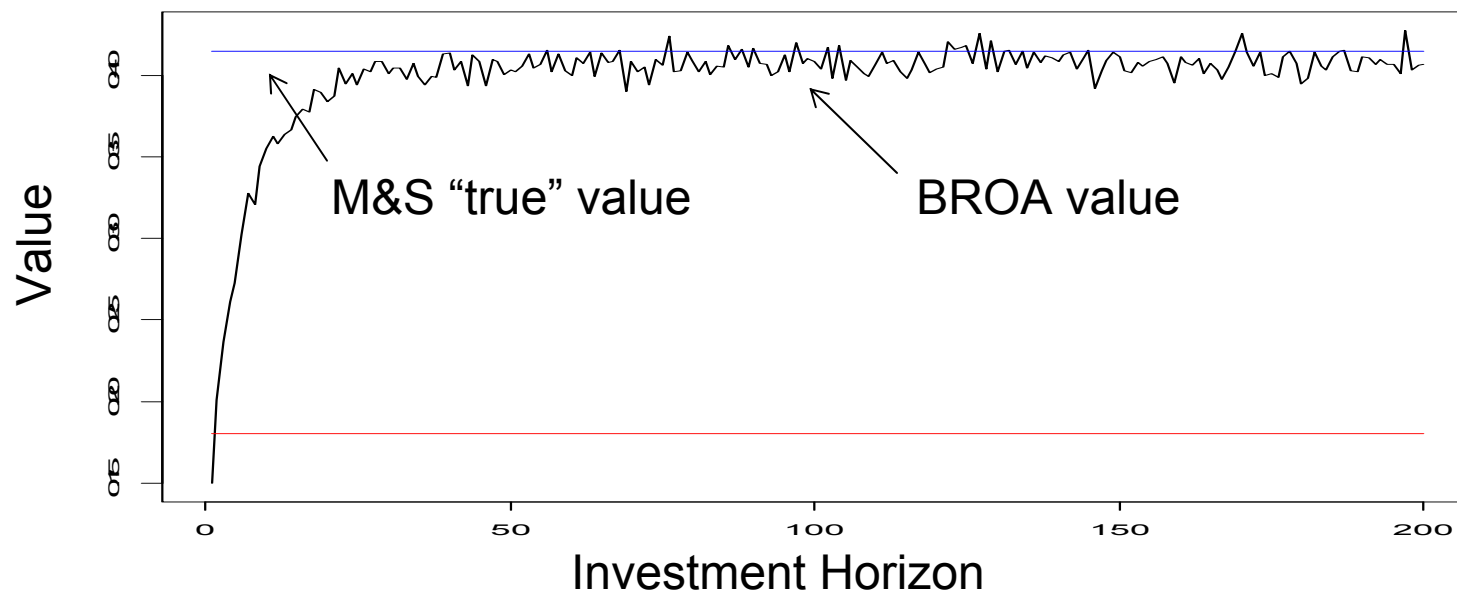
- BROA value quickly converged on exact analytical formula value, despite using discrete time simulation and finite horizon

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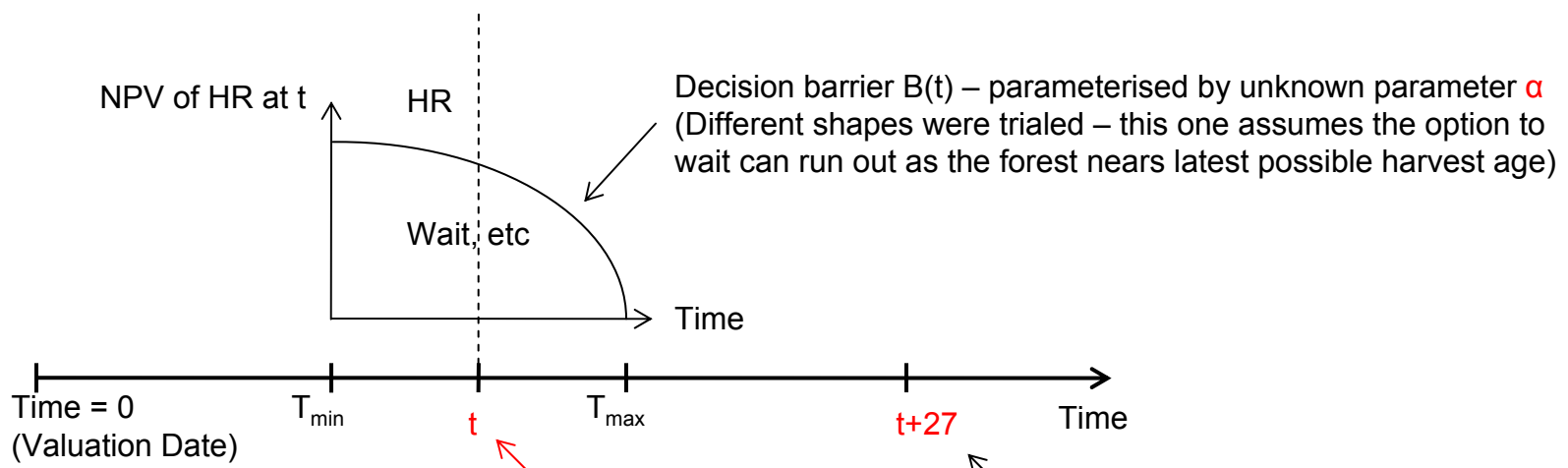
BROA – Post-1989 Forest Valuation

- Simplest scenario – assume land conversion is not possible (i.e. land is forestry only)

- Also assume harvest can only take place between times T_{min} and T_{max} (related to forest age)

- Forester's possible decisions, at any given time t inside this harvest window, are:
  - **Harvest and replant** (HR) if payoff (including DCF value from subsequent decisions) exceeds decision barrier
  - **Wait** if HR payoff is less than barrier and $t < T_{max}$ or
  - **Abandon** or **Carbon farm** (whichever is best) if $t = T_{max}$ and HR payoff is still less than barrier

BROA – Post-1989 Forest

For given simulation trial, and candidate value of decision barrier parameter (α) …

Based on computed decision values at t, either:
- Harvest and replant (HR) if NPV of HR at t ≥ Decision barrier B(t)
- Wait if NPV of HR at t < B(t) and t < T_{max}
- Abandon or carbon farm (better of) if t = T_{max} and NPV of HR at t < B(t)

NPV of HR at t

HR

Wait, etc

Time

Decision barrier B(t) – parameterised by unknown parameter α
(Different shapes were trialed – this one assumes the option to wait can run out as the forest nears latest possible harvest age)

Time = 0
(Valuation Date)

T_{min}

t

T_{max}

t+27

Time

Simulate price paths up to candidate first decision date t to compute NPV of possible HR decision at t – we "know" all current prices as at t

Candidate decision date t
(becomes T* if decision other than "wait" is crystallised, in which case NPV at time 0 for the given trial and α can then be computed based on NPV of decision at time t and net cash flows derived up to t)

NPV of HR at t depends on decisions taken at t+27 (i.e. HR, abandon, carbon farm), and hence on values arising after t+27 – compute these values using DCF and expected future prices conditioned on prices "known" at t

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BROA – Post-1989/Pre-1990 Valuation

- Repeat the above for 5,000-10,000 MCS trials, and take the mean NPV to estimate forest value <u>given that α value</u>

- Finally, repeat the whole exercise for various values of α, taking <u>optimal</u> α to be that producing the highest forest value

- Approach becomes more involved for <u>pre-1990</u> forests since deforestation (i.e. conversion) option must now be modeled – within decision window forester can either:
  - **Harvest and replant** if payoff is "sufficiently high" (no deforestation liability)
  - **Harvest and convert** if payoff is "sufficiently high" (including deforestation liability) or
  - **Abandon** the forest if $t=T_{max}$ and neither of harvest or conversion is feasible

  PLUS 1-D posited harvest <u>barrier</u> now becomes a 2-D posited "Harvest <u>map</u>" (see over), with at least <u>two</u> unknown parameters – α and β

- Pre-1990 model is easily adapted for <u>post-1989 valuation including conversion</u> → decision and payoff details change, but basic approach remains the same

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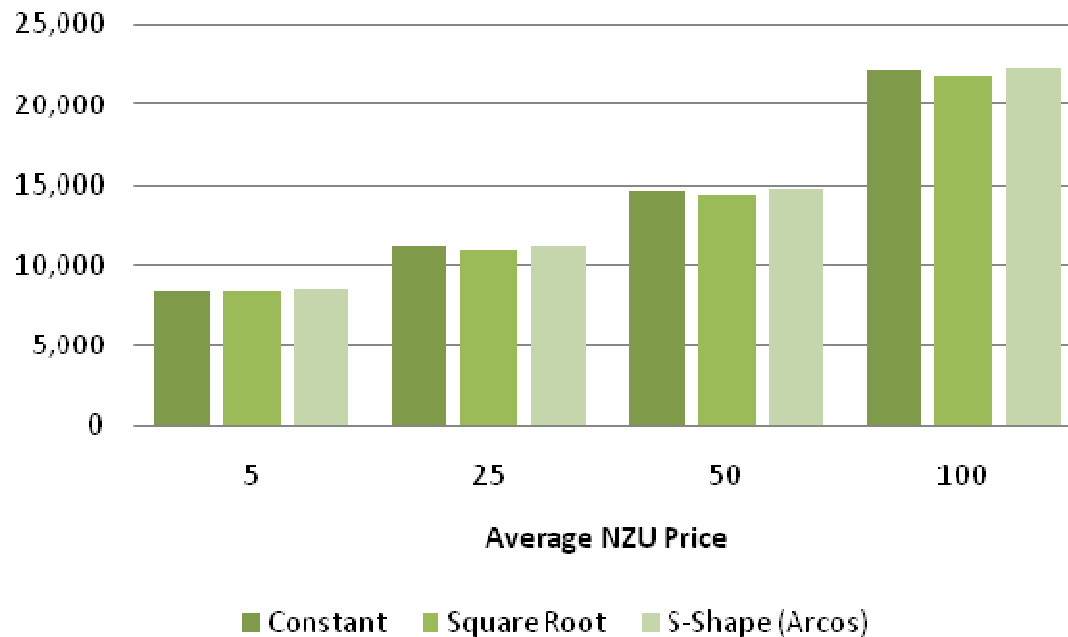
BROA – <u>Pre-1990</u> Forest Decision <u>Map</u>
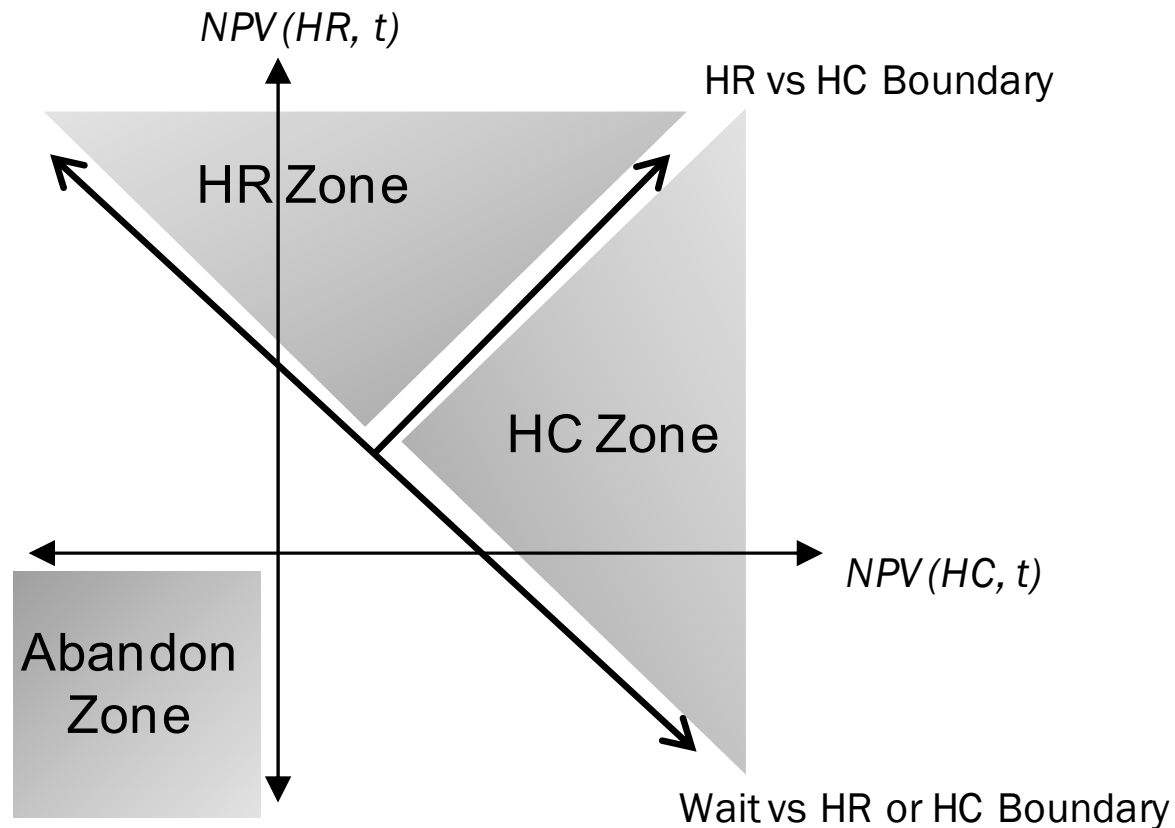
But let's not get into that now …

Post-1989 Non-Conversion Results

Greenfields *P. Radiata* Forest Value (NZ$/ha) as at 1 January 2008 versus Average NZU price (NZ$/tCO$_2$) for three decision barrier shapes (illustrative assumptions, mean-reverting prices):


Also find average harvest age exceeds norms (27 years), and harvest probability generally very high but falls quickly for very high carbon price

Pre-1990 Conversion Model Results

18 year old *P. Radiata* Forest Value (NZ\$/ha) as at 1 January 2008 versus Average NZU price (NZ\$/tCO$_2$) for three average dairy land values (NZ\$/ha, representing value secured on conversion/deforestation):

Average NZU Price

■ Avg. Dairy Land = \$10k   ■ Avg. Dairy Land = \$20k   ■ Avg. Dairy Land = \$50k
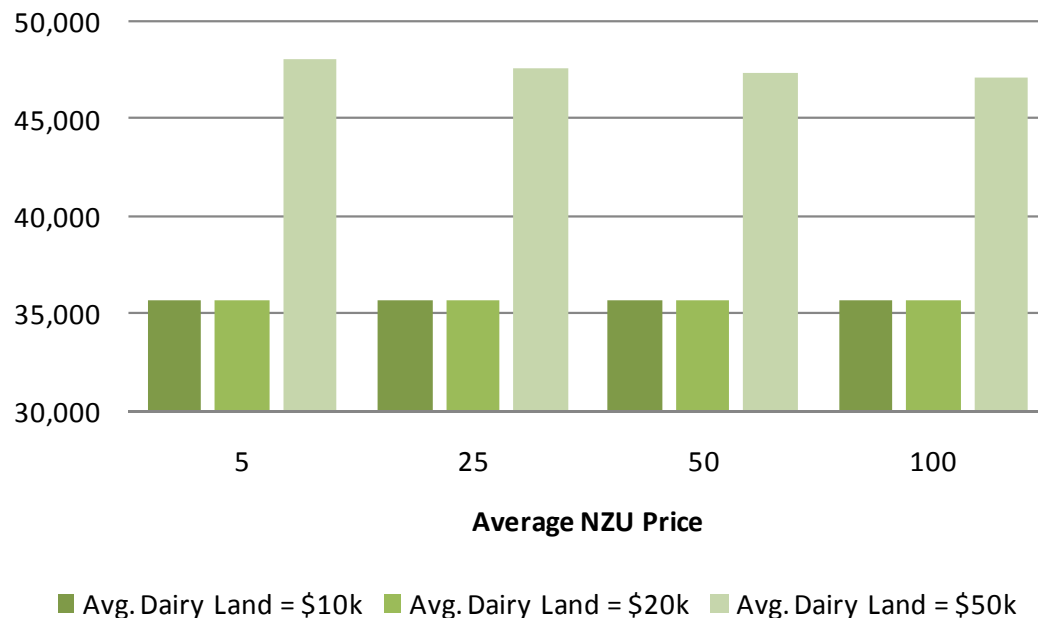
Find negligible conversion probability for all NZU price levels except when average dairy land values are very high, in which case average harvest age falls relative to norm

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Pre-1990 Model with 8 Year Trick

Value change relative to 18 year old *P. Radiata* Forest Value (NZ$/ha) as at 1 January 2008 versus Average NZU price (NZ$/tCO$_2$) for three average dairy land values (NZ$/ha), assuming deforestation delayed >8 years after harvest
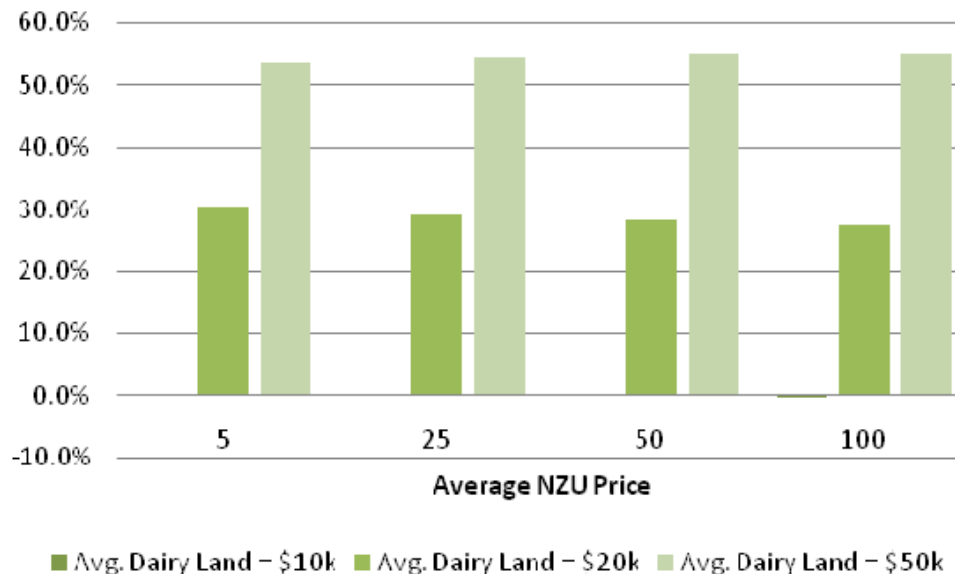
Dairy conversion more viable even for moderate dairy land values across all NZU prices if harvested land is "parked" and deforestation occurs >8 years from harvest instead of immediately

Conclusions

- Under carbon pricing foresters may become carbon farmers instead of lumberjacks, or committed foresters instead of possible dairy farmers → richer land use decisions

- BROA forest valuation outputs change as expected for changes in key decision variables (carbon price, dairy land value), and appear to be fairly insensitive to the form of decision barrier/map posited

- BROA approach trades off accuracy for tractability while allowing for considerable flexibility and complexity

- Its results, while approximate, should be significantly more accurate than DCF, and it captures more of the valuation problem's features

- A significant merit of the approach is that it can be implemented in a spreadsheet! (e.g. with @RISK)

- As technology improves and exact solutions can be formulated (and perhaps even implemented), the approach's compromises may no longer be required

- In the meanwhile BROA fills a significant gap in the valuation literature, and can potentially be applied to other complex valuation problems for which conventional ROA is intractable

Thank You – Any Questions?

Source: NZIF, *Forestry Handbook*, 2005