Risk and Uncertainty in Forest Carbon Sequestration Projects

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Risk and Uncertainty

- Optimal decisions change when risk or uncertainty explicitly recognised
- Risk: multiple outcomes with known probability (contrast with the loss function defined by Statistical Decision Theory)
- Uncertainty: outcome probabilities unknown
Categories of risk / uncertainty

- Forest dynamics or growth
- Inventory or stock
- Preference function
- Internal sources
  - Simplifications required for models
  - Inaccuracies in data or projections
- External sources
  - Changing nature of desired state
  - Improper specifications of returns
Carbon Pools

- Tree biomass
  - Bole
  - Bark, twigs, leaves
  - Roots
- Soil
- Litter and debris
- Products (off-site)
Change or Standing Inventory

- Amount sequested between 2008 and 2012
- Amount present in 2008 and 2012
- Independence of estimates
CAMFor

- Carbon Account Modelling for Forests
- Developed by NCAS (AGO)
- Based on FORTRAN code of CO$_2$Fix
  - Modifications to number of pools and management activities
Inputs to CAMFor

- Bole volume increment (CAI m³ha⁻¹yr⁻¹)
- Relative allocation to branches, bark, leaves, twigs, roots
- Rates of transfers between pools and atmosphere
- Density and Carbon Content
- Soil
Inputs to CAMFor

- **Management regime**
  - Intensity and timing of harvests
  - Products
  - Area established by year

- **Fire**
CAI \( m^3ha^{-1}yr^{-1} \)

- Modelled growth
- Assumptions about model coefficients
- Localised biases in output (weather cycles)
- Model domain
- Bias and precision of input
  - Site Index
Model imprecision
Localised bias
Modelled risk in CAI
Allocation to other biomass pools

- Proportional allocation
- Annual movement between pools
- Multipliers to original fractions to ensure pool ratios (expansion factors) reasonable
- Simple correlations assumed
Simulation of growth change

- Nth Coast NSW *Eucalyptus* plantation
- Sequestration from 2008-2012 (tree carbon t/ha)
- Plantation established in 1990
- No harvest or fire
Dominating risks

- Localised weather biases
- Density Carbon content
- Site Index
- Allocation of annual growth

<table>
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<th>X-axis: Standard error of regression coefficient</th>
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Simulation of different establishment years

- Sequestration from 2008-2012
- Maximum sequestration for 2002 - 2006
- Maximum imprecision in same period
- Unequal variations
Simulation of management impacts

- Partial thinning at age 12 years
- Plantations established between 1990 and 2000 (harvest before end of Kyoto Commitment Period)
Simulation of full estate

- **Soil carbon**
  - 100 - 300 t(C)ha at establishment
  - Decrease $0.97 \text{year}^{-1}$ for 5 years (0.94 - 1.0)
Simulation of full estate

- **Mapping error**
  - Boundaries within 5 or 10 m of true
  - Error in area can exceed 40% for small plantations with systematic 10 m boundary error

- **Management**
  - Estate of 500 ha planted each year from 1990 - 2010 (area boundary within 5 m)
  - Thinned at age 12 years
Carbon (t/ha) sequested
Conclusions

- Predicting change is different to predicting standing stock
- Variability in the change for a given period is influenced by:
  - Actual growing conditions in that period
  - Relative location on the CAI curve
- Management options
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