



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 sequestered 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 CO₂Fix**
 - **Modifications to number of pools and management activities**



Inputs to CAMFor

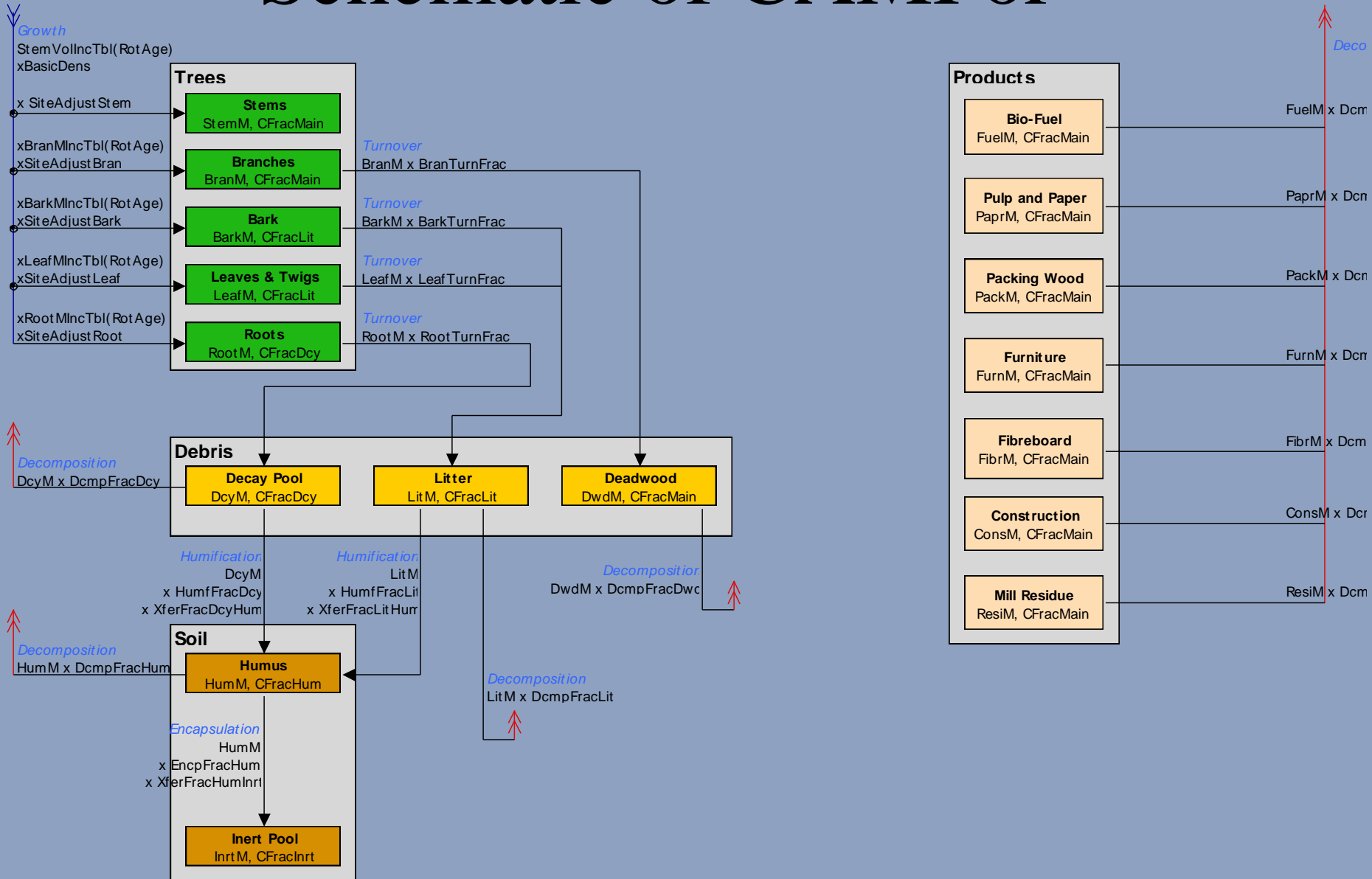
- **Bole volume increment (CAI $\text{m}^3\text{ha}^{-1}\text{yr}^{-1}$)**
- **Relative allocation to branches, bark, leaves, twigs, roots**
- **Rates of transfers between pools and atmosphere**
- **Density and Carbon Content**
- **Soil**



Inputs to CAMFor

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

Schematic of CAMFor



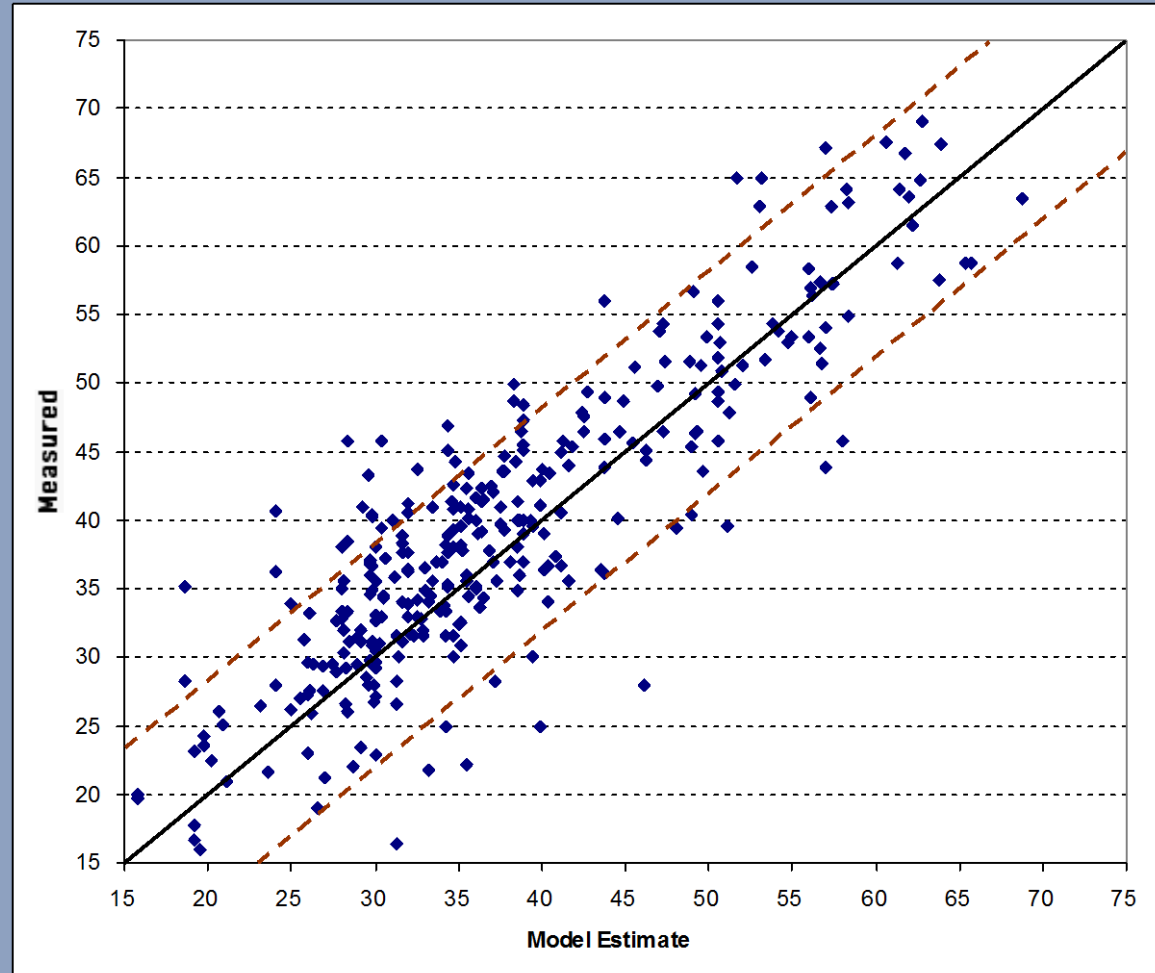


CAI $\text{m}^3\text{ha}^{-1}\text{yr}^{-1}$

- **Modelled growth**
- **Assumptions about model coefficients**
- **Localised biases in output (weather cycles)**
- **Model domain**
- **Bias and precision of input**
 - **Site Index**

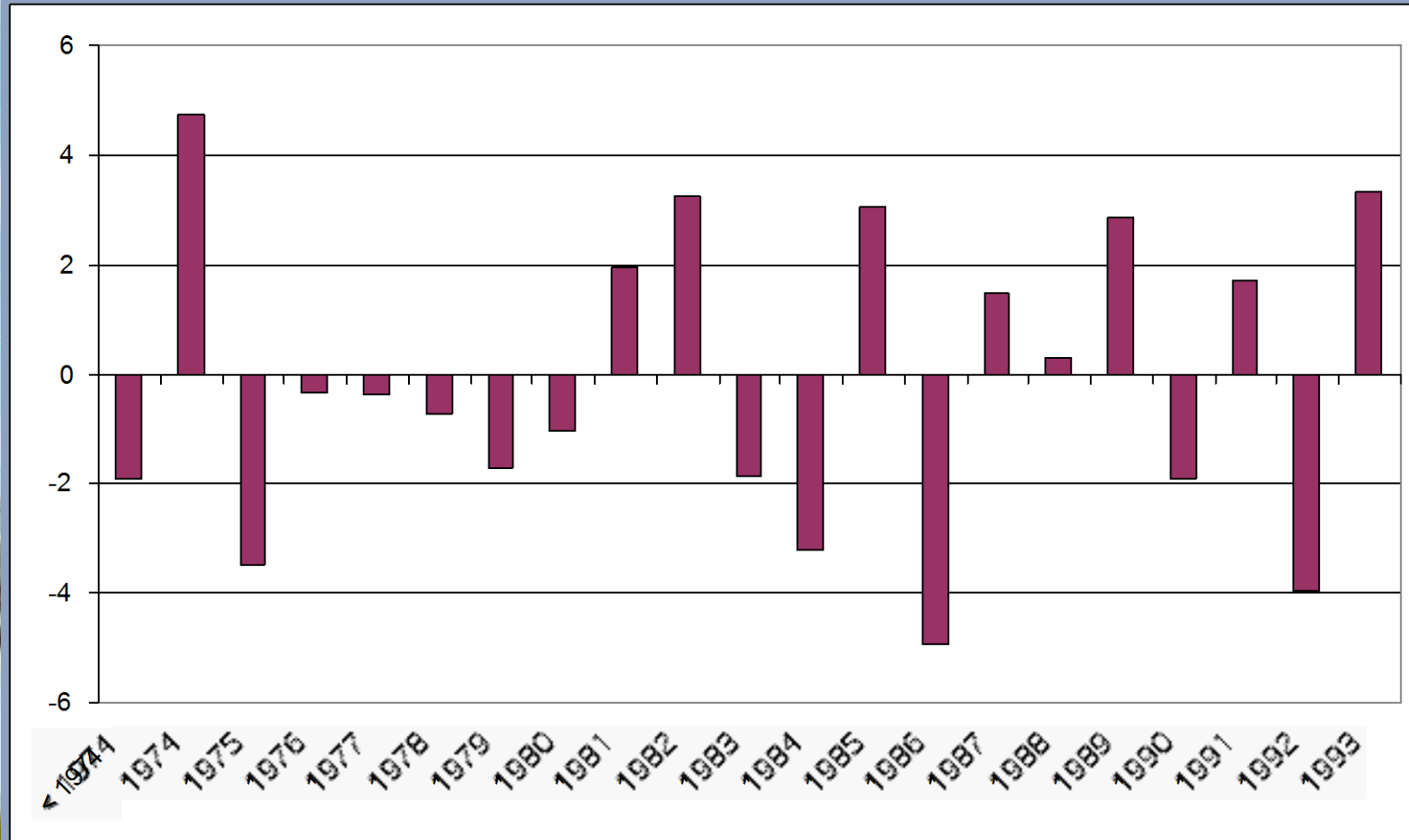


Model imprecision



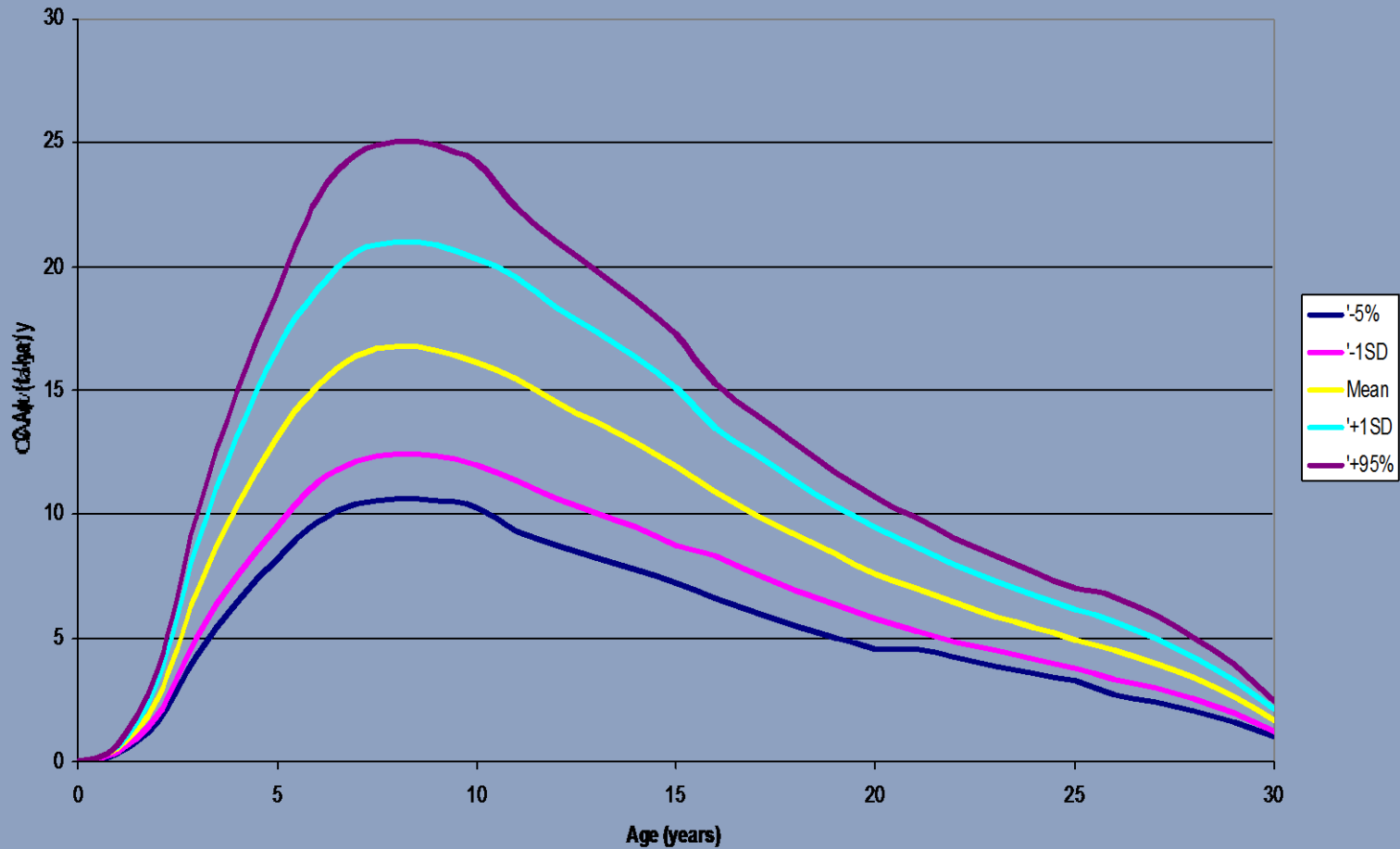


Localised bias





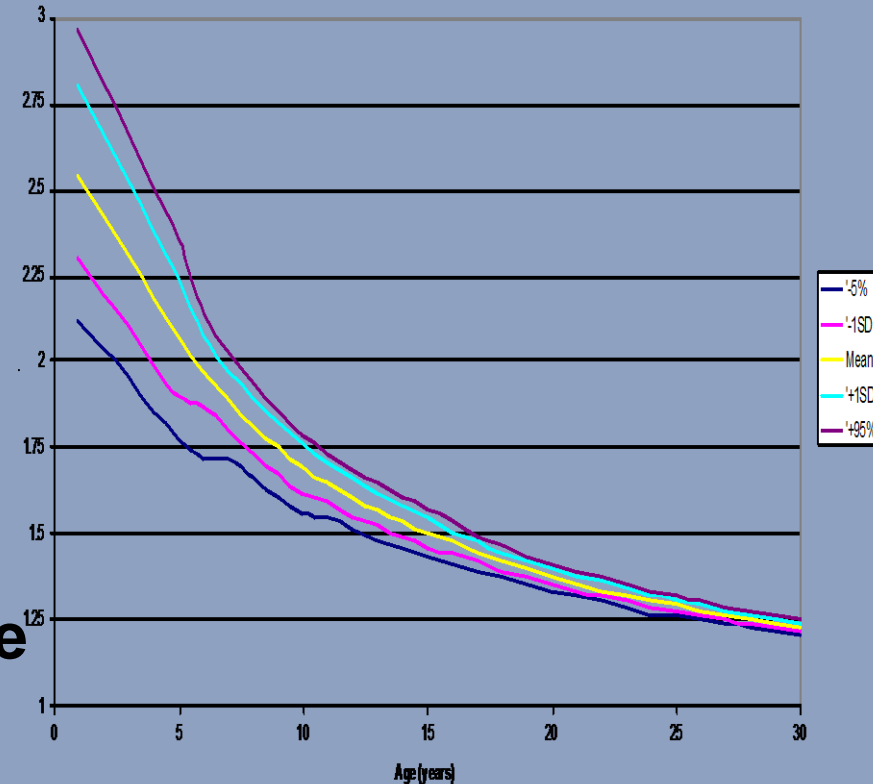
Modelled risk in CAI





Allocation to other biomass pools

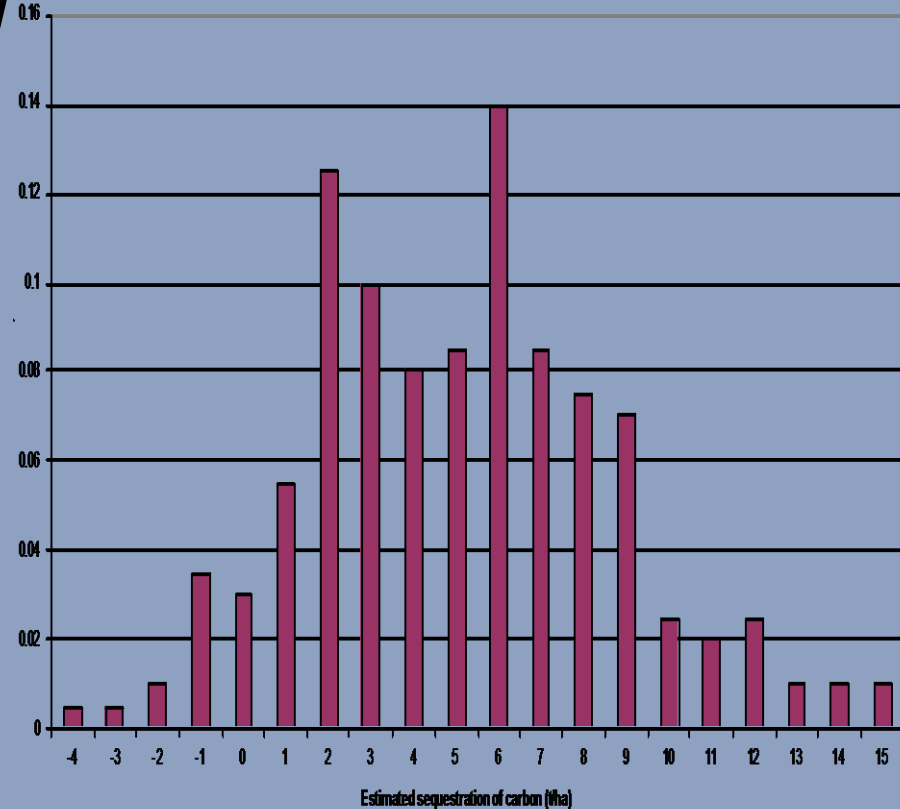
- Proportional allocation
- Annual movement between pools
- Multipliers to original fractions to ensure pool ratios (expansion factors) reasonable
- Simple correlations assumed





Simulation of growth change

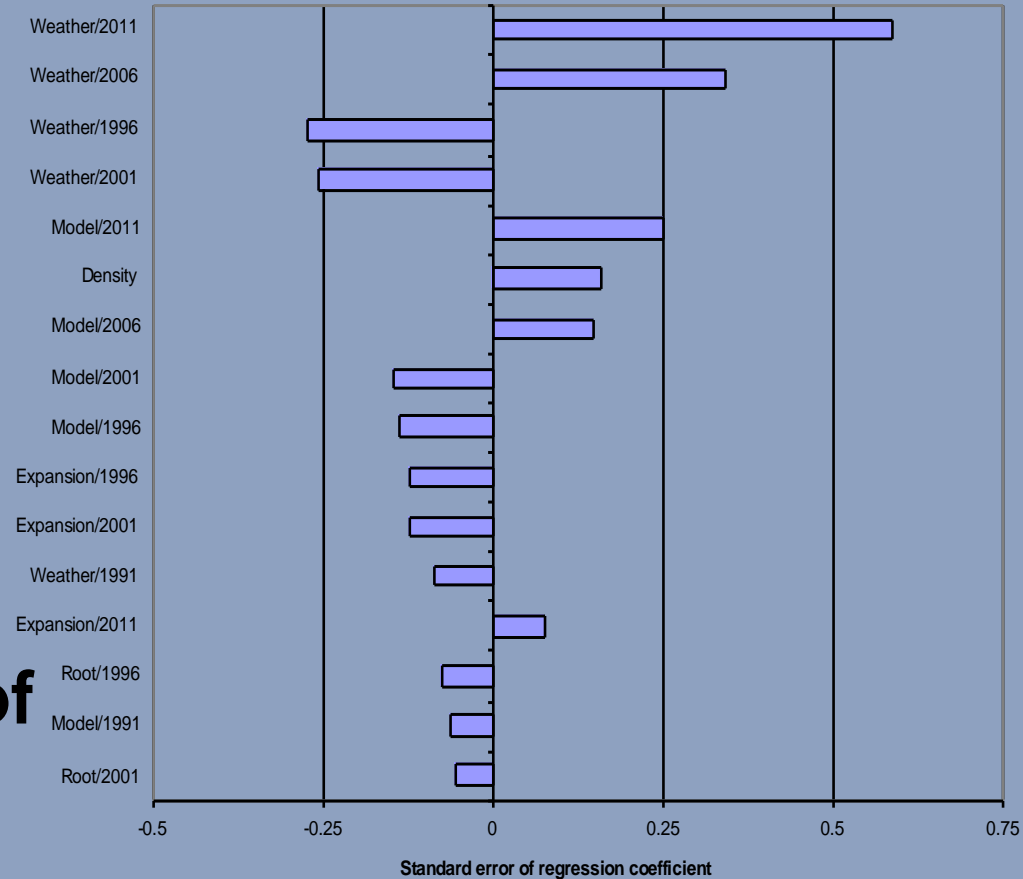
- Nth Coast NSW *Eucalyptus* plantation
- Sequestration from 2008-2012 (tree carbon t/ha)
- Plantation established in 1990
- No harvest or fire





Dominating risks

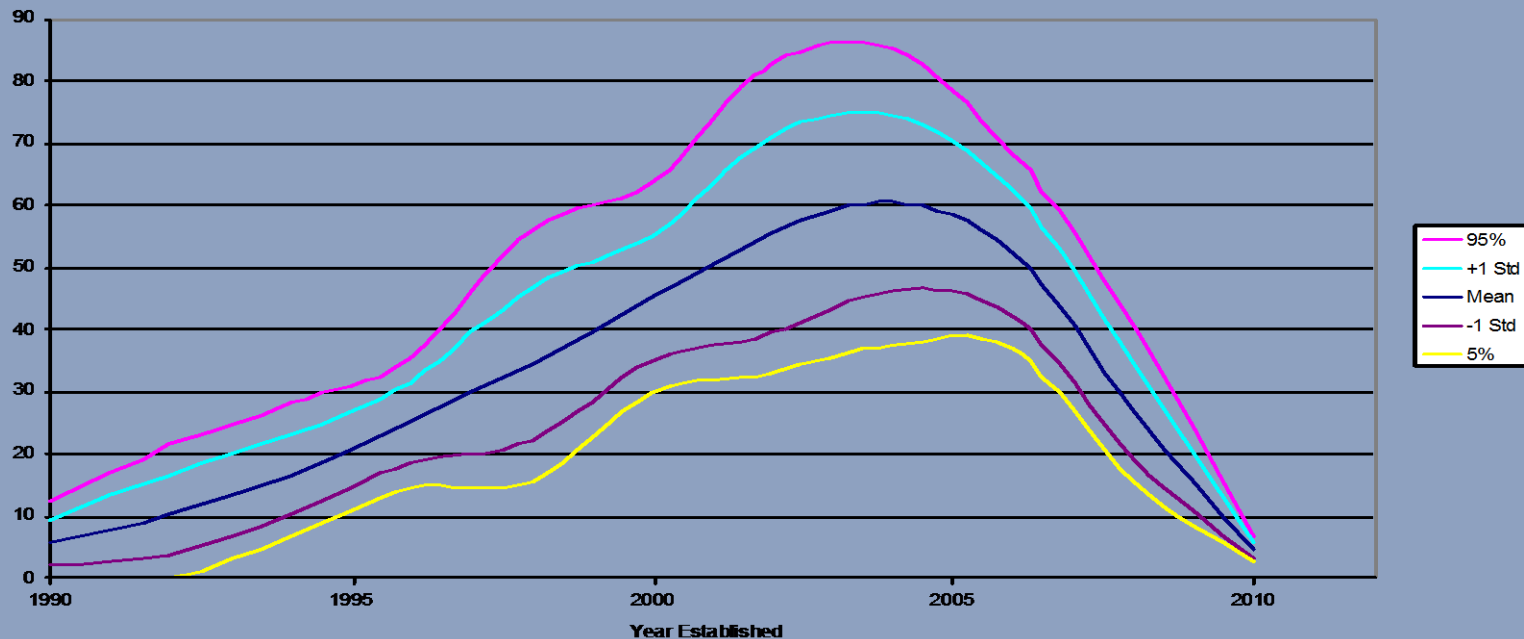
- Localised weather biases
- Density Carbon content
- Site Index
- Allocation of annual growth





Simulation of different establishment years

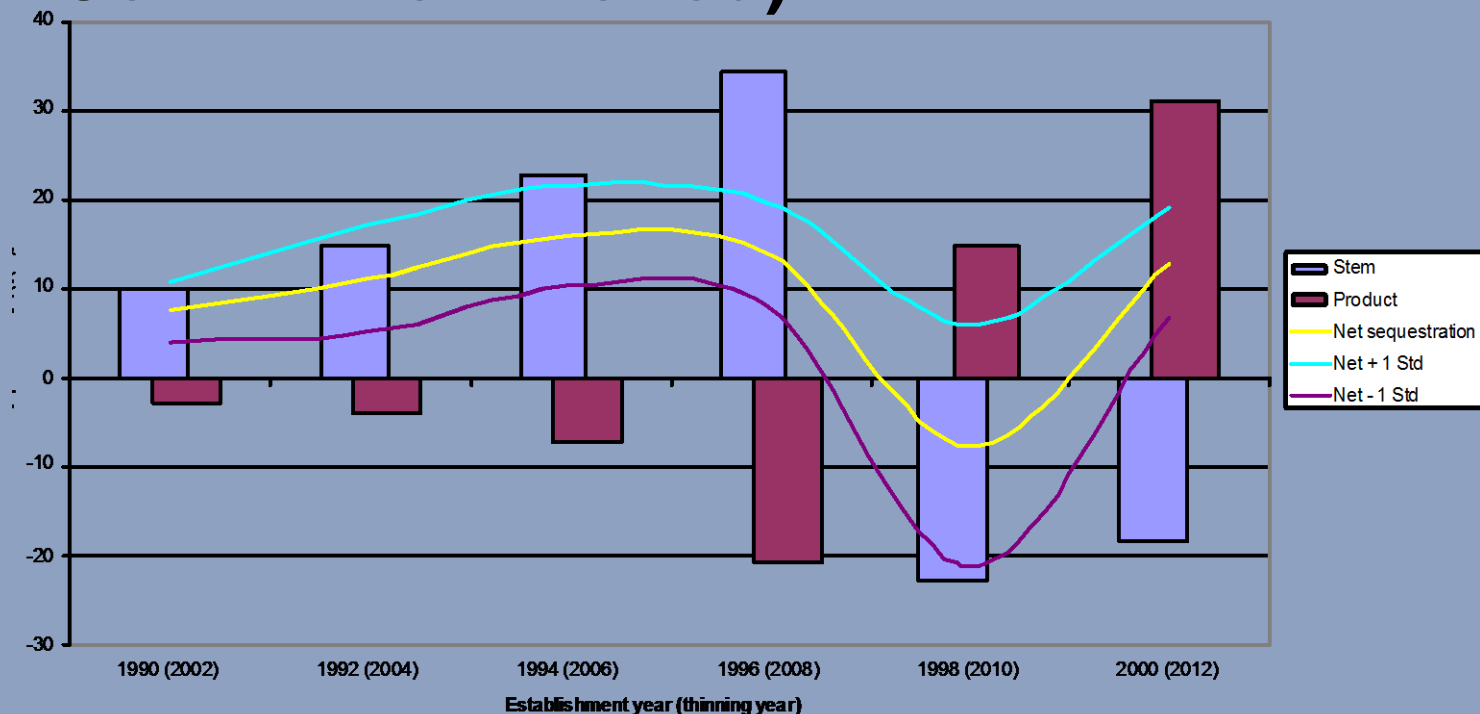
- Sequestration from 2008-2012
- Maximum sequestration for 2002 - 2006
- Maximum imprecision in same period
- Unequal variations





Simulation of management impacts

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

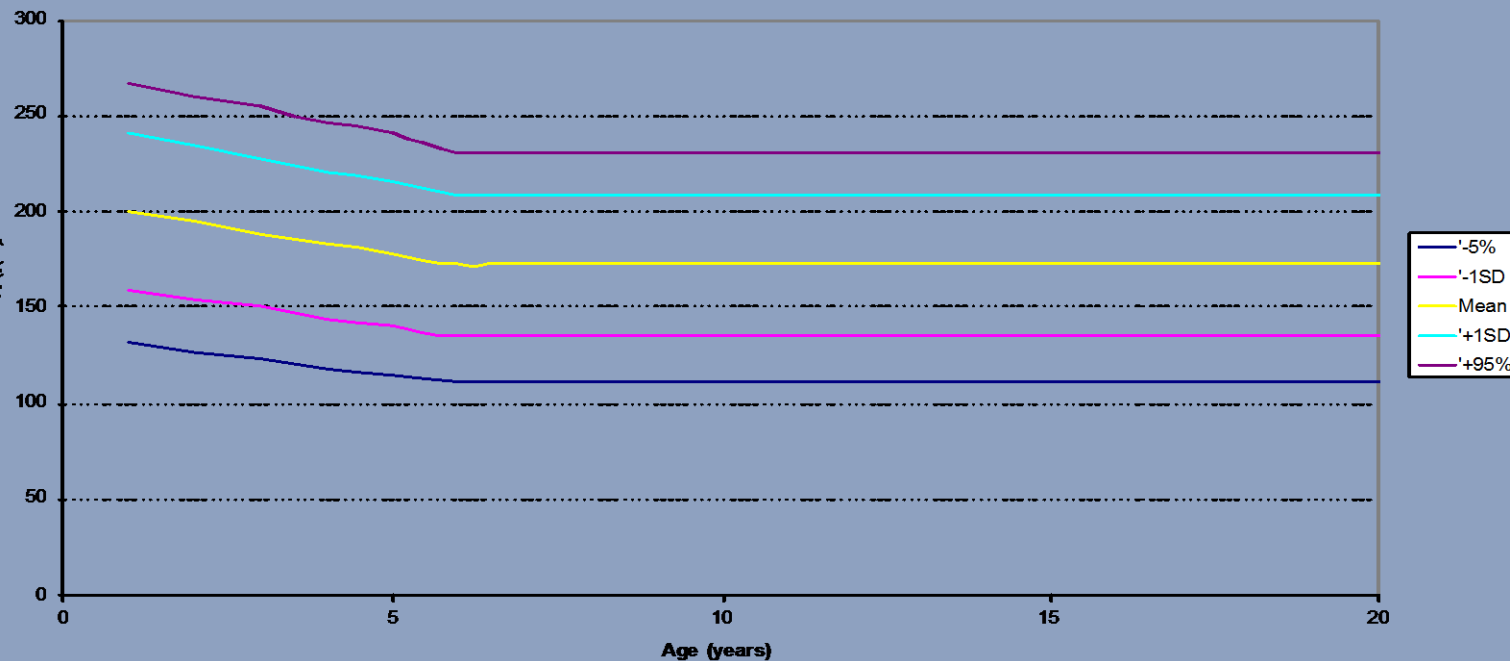




Simulation of full estate

● Soil carbon

- 100 - 300 t(C)ha at establishment
- Decrease 0.97year^{-1} for 5 years (0.94 - 1.0)





Simulation of full estate

- **Mapping error**

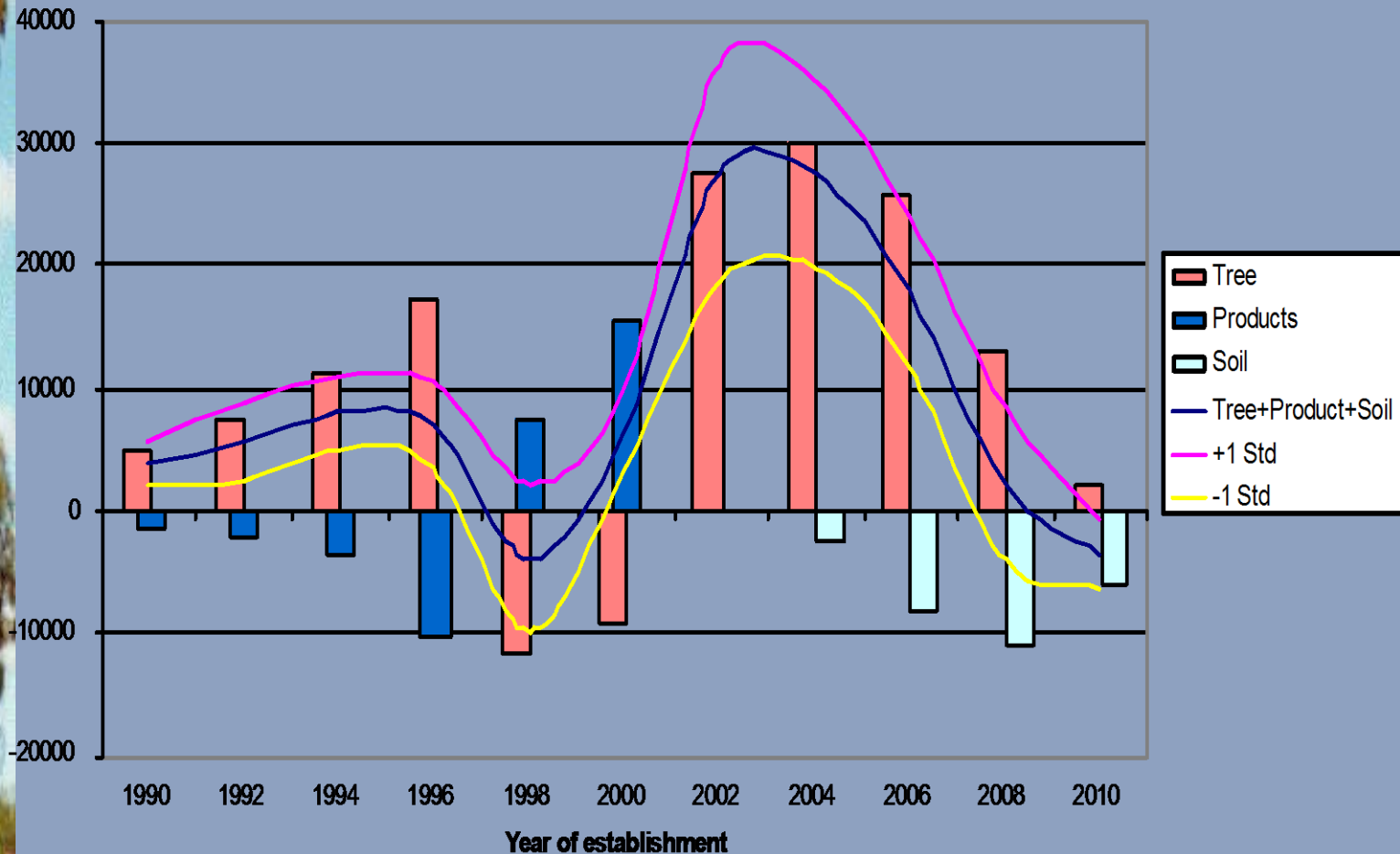
- Boundaries within 5 or 10 m of true
- Error in area can exceed 40% for small plantations with systematic 10 m boundary error

- **Management**

- Estate of 500 ha planted each year from 1990 - 2010 (area boundary within 5 m)
- Thinned at age 12 years



Carbon (t/ha) sequestered





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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