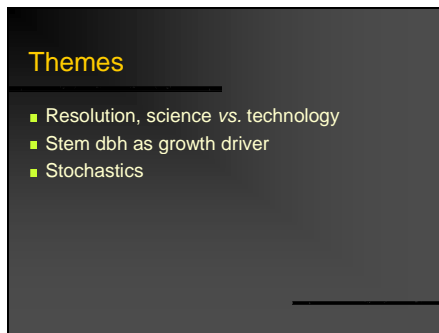
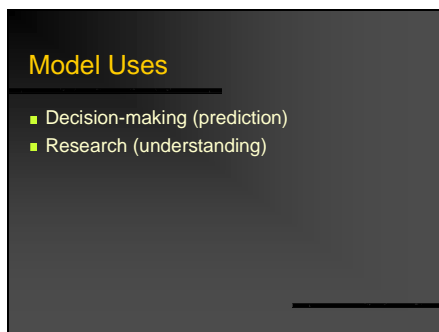


Presented at the  
***2002 Western Mensurationists' Meeting,***  
Leavenworth, Washington, 23-25 June  
2002.



There is a perception that most growth modelling problems have been solved and that there are now satisfactory recipes. However, complacency with current orthodoxy can/should be challenged. There is still much to be done (after all, I'm paid for that!) Even for "simple" stands. I shall question some of our present practices and assumptions, mostly around these three themes. More questions than answers for now.



Misunderstandings and unnecessary controversy from failing to distinguish different modelling objectives.

## Management Decision-making



- Prediction
- Precision
- Controllable variables
- Match:
  - Available input info
  - Required output info

## Scientific Research

- "Process models"
- Mechanistic, realistic
- Detailed
- Qualitative behavior
- Generate questions



“Science” used to be seen with suspicion in relation to “Practice”. The situation has been reversed in the last decade or two.

Grants can be obtained if one can prove that the research won't have any practical use whatsoever. “If it is useful, it should be funded by Industry”. But a company only funds work on problems specific to it, or results that could be appropriated. Not research that would raise the efficiency of the whole forestry sector. Worldwide, applied forest research has fallen through the cracks.

## Science vs. Technology



N, S, W, E

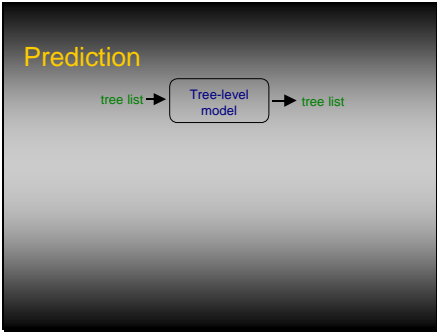
Journal of  
Applied Forestry

Few outlets for applied forest research. To (some?) forest research journals only “scientific” results (p-value computations?) are acceptable, “technology” is not.

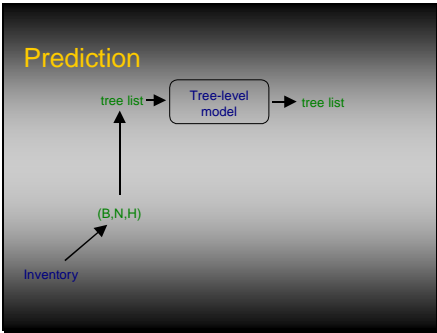
Limits also to technological research in general journals addressed to practitioners?



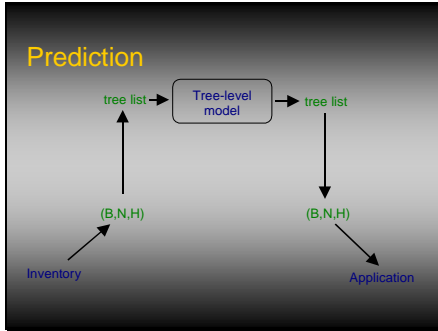
“Applied Forestry”. Think about it!  
Don’t know exactly what the other kind of Forestry is, but will be talking here about the applied sort.



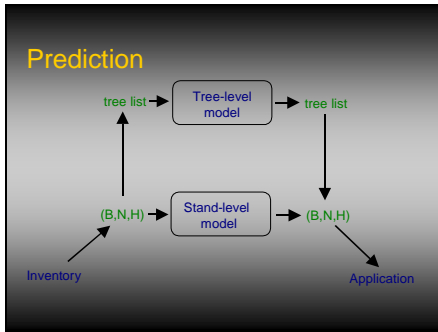
“Traditional” growth models these days project tree-level values, with or without coordinates (e.g., tree lists)



Reliable info at the tree level is rarely available. Decent estimates from operational forest inventory may be expected only for stand level aggregates (e.g. basal area, stand density, top height). *Tree list generation* or other techniques are used to fake the initial conditions required by the growth model.



Often projections are summarized for decision-making.

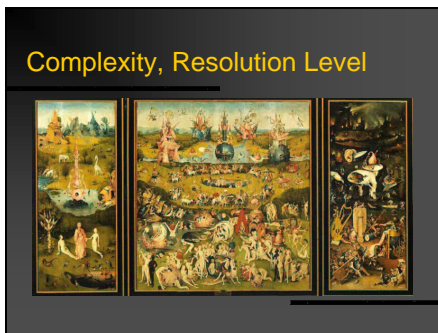


An (unfashionable) alternative is to attempt projecting directly the information available.

More difficult to enforce plausible behaviour in stand-level models.

*Plausible but wrong* more dangerous than *obviously wrong*?

Yes, we do not know how to make good stand-level models for uneven-aged and multi-species stands (yet!)



The world is complicated. No limit to the level of detail that can be included in a model.

## Complexity, Resolution Level

"Model at one level of detail below the level desired for prediction"

Statement in a recent forest growth modelling state-of-the-art address. Today's consensus?  
(Semantic nitpicking: "below" or "above"?)  
Sounds good.

## Complexity, Resolution Level

"Model at one level of detail below the level desired for prediction"

- Understanding: Two levels higher?
- Prediction: Same level

Disagree, at least for decision-making.  
Maybe for research models, although more detail might be desirable (what exactly do we mean by level of detail?)  
For decision-making, in fields other than Forestry (Management Science, Control Theory, etc.) it is well established that redundancy should be minimized. A model should connect as directly as possible actions to consequences.

## Complexity, Resolution Level

"Model at one level of detail below the level desired for prediction"

- Understanding: Two levels higher?
- Prediction: Same level

Links

Desirable to establish links between models at different levels. Benefits in both directions:  
To incorporate scientific knowledge into management models.  
To study higher-level emergent properties that escape to the reductionist approach.  
Two ways:  
Empirical fitting of simple models to complex models.  
Mathematical relationships between models at different levels.

### Growth Drivers

$$\Delta v = f(\text{age}, \text{dbh}, \text{site}) ?$$

Empirical models work fine in many situations. For extrapolation, a more mechanistic basis might be desirable. Can use knowledge from more detailed research models.

To predict tree or stand growth, which are the variables that first spring to mind?

Many foresters/modellers would probably think of those above.

### Growth Drivers

$$\Delta v = f(\text{age}, \text{dbh}, \text{site}) ?$$

height

First, while saying “age” one is probably thinking “size”. Age, as elapsed time, does not have a physical presence in the stand (other than as number of growth rings), so it should not have a causal effect. It is size that matters

Not much difference in practice, because of the close relationship between age, height and site. But cleaner, more logical, to use height instead.

Dealing with a particular stand, site may be omitted to simplify notation (usually taken as constant).

### Growth Drivers

$$\Delta v = f(\text{height}, \text{dbh})$$

Growth driven by stem thickness?

How does the amount of dead xylem accumulated on the stem affect tree growth?

There may be some extreme limiting relationships, related to mechanical support.

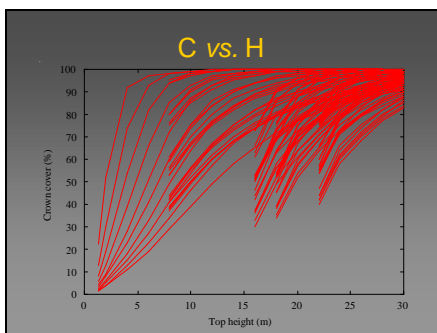
But normally it should be largely irrelevant.



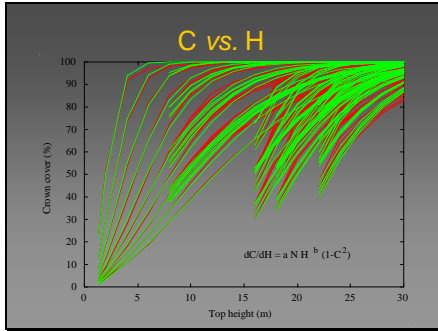
## Stand-level

$$\begin{aligned}\Delta V / \Delta H &= f(H, N, C) && \text{(Eichhorn 1904)} \\ \Delta N / \Delta H &= g(H, N, C) \\ \Delta C / \Delta H &= h(H, N, C)\end{aligned}$$

Just to prove a point, a stand-level model called TADAM closely approximated all the planted Douglas-fir TASS yield tables from TIPSYS. TADAM is entirely empirical, using as state variables top height, stems per hectare and basal area (H,N,B). Good enough for most practical purposes. But if pushed too far, might break. Like self-thinning lines and stand density management diagrams, which work fine for the unmanaged stand data on which they are usually based, but fail miserably under thinning. A more mechanistic diameter-free TASS approximation is in the works, using crown cover % (C) as an additional variable. TIPSYS (and TADAM, and the new model) uses Eichhorn's Law, implying that increments relative to top height increment are independent of site. Not essential, but simplifies things a little. Following TASS, stand volume increment (relative to H) varies with H, N, and C. No B, V or D! Similarly mortality. Need also an equation for C. For the initial crown closure process, and its recovery after thinning.



I'll show only crown cover. TASS simulations (in TIPSYS yield tables) of crown cover for planted lodgepole pine. Unthinned, pre-commercially thinned, and commercially thinned stands.

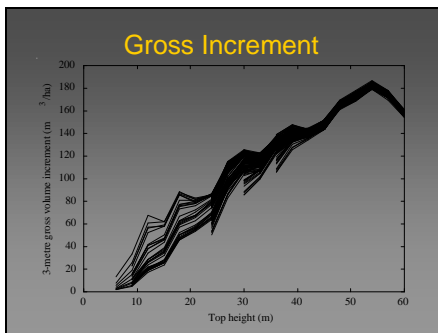


Model predictions (green), from initial point of each yield table.  
 Actually, differential equations are used instead of the finite increments shown before.  
 Degree of approximation limited by random fluctuations in the simulations (TASS is a stochastic model).  
 Same for TADAM.  
 Randomness more noticeable for volume/basal area, and especially mortality.

**Stochastic Models**

- Convenient for the modeller
- Variability info?
- In practice, single realization


Easier to model mortality with stochastic models, for instance.  
 “Nature is variable; we should provide the decision-maker with full range of possible outputs”  
 Operationally, just one model run is normally used. Some simulators have the random numbers seed hardwired, not to confuse the user.  
 A deterministic model does not imply a deterministic world. May represent an average or most likely outcome.  
 Most likely outcome (and perhaps some rough idea of variability) is all that users want and need?



Example: gross stand volume increment (relative to H increment) in TIPSYS Douglas-fir yield tables.  
 One simulation for each treatment, presumably with the same random seed.

### Stochastic Models

- Convenient for the modeller
- Variability info?
- In practice, single realization
- Worse of both worlds?



Should at least average a number of simulations?

### Mind the Users!



[web.unbc.ca/~garcia](http://web.unbc.ca/~garcia)

Hand waving. Some pointers to more in website.  
Hope more than expectation: a few researchers in new generation might escape measuring success by number of publications, and tackle some Applied Forestry?  
Conclusion: *We are not there yet...*