Individual Tree Non-Spatial Modeling in Boreal Mixedwoods

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Mixedwood Growth Model (MGM) Development

- Funding (2004 → 2006)
  - Forest Resource Improvement Association of Alberta
  - Mixedwood Management Association (MWMA)
  - Western Boreal Growth and Yield Association (WESBOGY)

- Strategic Development Team
  - Modelers (University of Alberta)
  - Silvicultural researchers (University of Alberta)
  - Forest industry (MWMA, WESBOGY)
  - Government (Alberta Sustainable Resource Development)

- More info: www.rr.ualberta.ca/research/mgm/mgm.htm

Individual Tree Non-Spatial Modeling (MGM)

- Examples:
  - FVS /Prognosis, Mixedwood Growth Model (MGM)
- Purpose:
  - Project tree-lists for boreal pure and mixed stands:
    - Aspen / balsam poplar, white spruce, lodgepole pine
  - Capacities:
    - Establishment, growth and removal (thinning and harvest) tools
    - Handles site conditions through site index and taper
    - Models inter-tree competition

Individual Tree Non-Spatial Modeling (MGM)

- Structure:
  - Tree-list driven:
    - Species, dbh, tree expansion factor (# of plots fit into 1 ha), height, total and/or breast height age

trSpp	trDbh	trpha	trHt	trAge	trBHAge
Aw	3.5	91.00	4.1	10	8
Aw	3.5	91.00	4.0	10	8
Aw	3.3	91.00	3.5	10	8
Aw	3.7	91.00	4.0	10	8
Aw	3.1	91.00	3.2	10	8
Sw	3.0	36.67	2.6	23	8
Sw	2.4	36.67	2.1	23	8
Sw	3.4	36.67	2.3	23	8
Sw	4.1	36.67	3.8	23	8
Sw	2.8	36.67	2.0	23	8
Sw	2.0	36.67	1.9	23	8
Sw	3.0	36.67	2.6	23	8

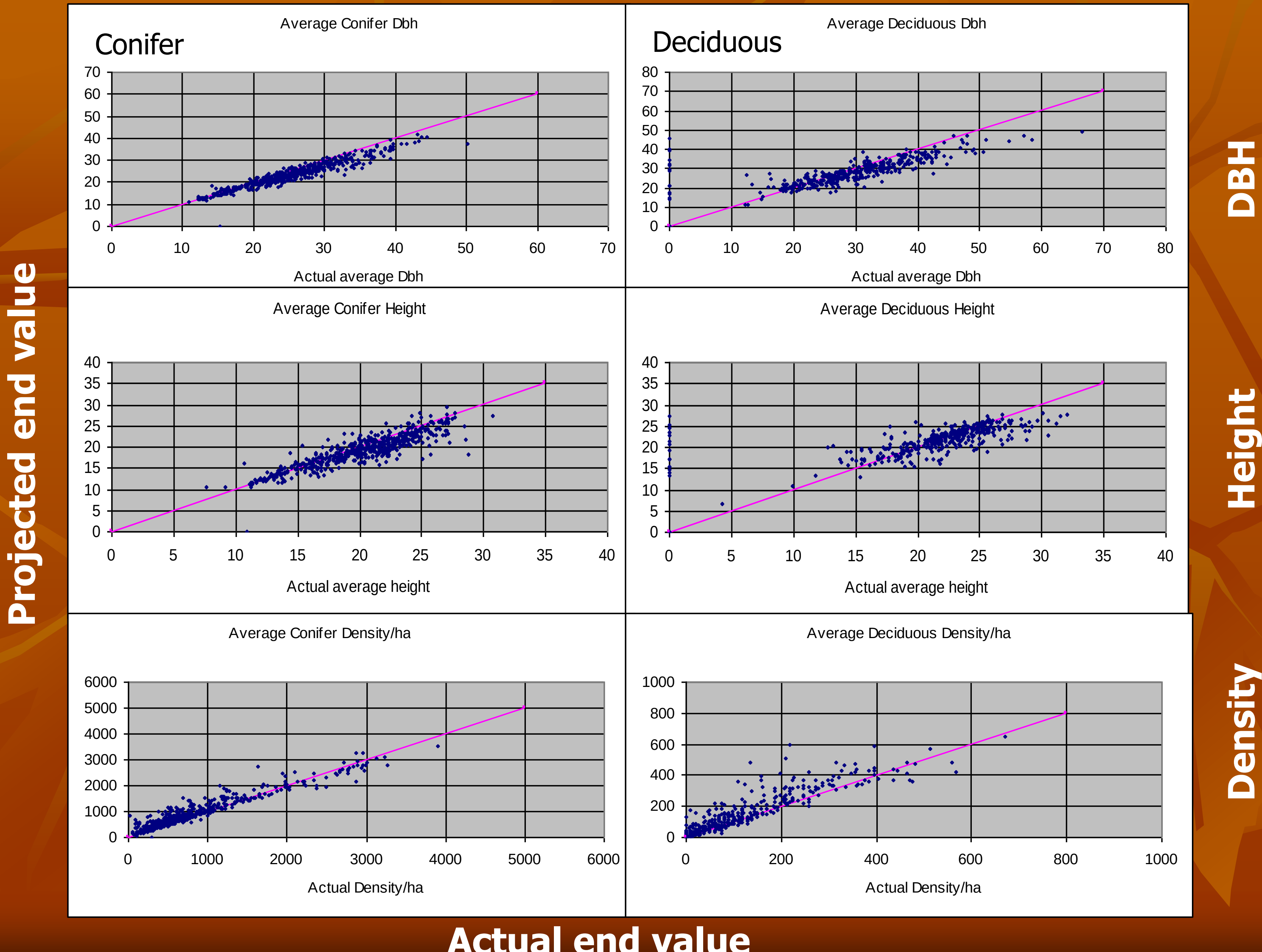
Stand

Individual Tree Non-Spatial Modeling

- Advantages:
  - mixed-species stand dynamics are simplified to modeling tree interactions
  - silvicultural treatments imposed on individual trees
  - tree lists are collected in ground-based inventories
  - tree-level spatial coordinates expensive to obtain; studies show limited benefit
    - Filipescu and Comeau in preparation, Stadt et al. submitted, Daniels 1976, Alemdag 1978, Lorimer 1983, Martin and Ek 1985, Daniels et al. 1986, Corona and Ferrara 1989, Holmes and Reed 1991, Wimberly and Bare 1996

- Disadvantages:
  - more detailed than whole stand models
  - more difficult to model fine-scale spatial interactions compared to spatial models

MGM Validation – Mature CD stands

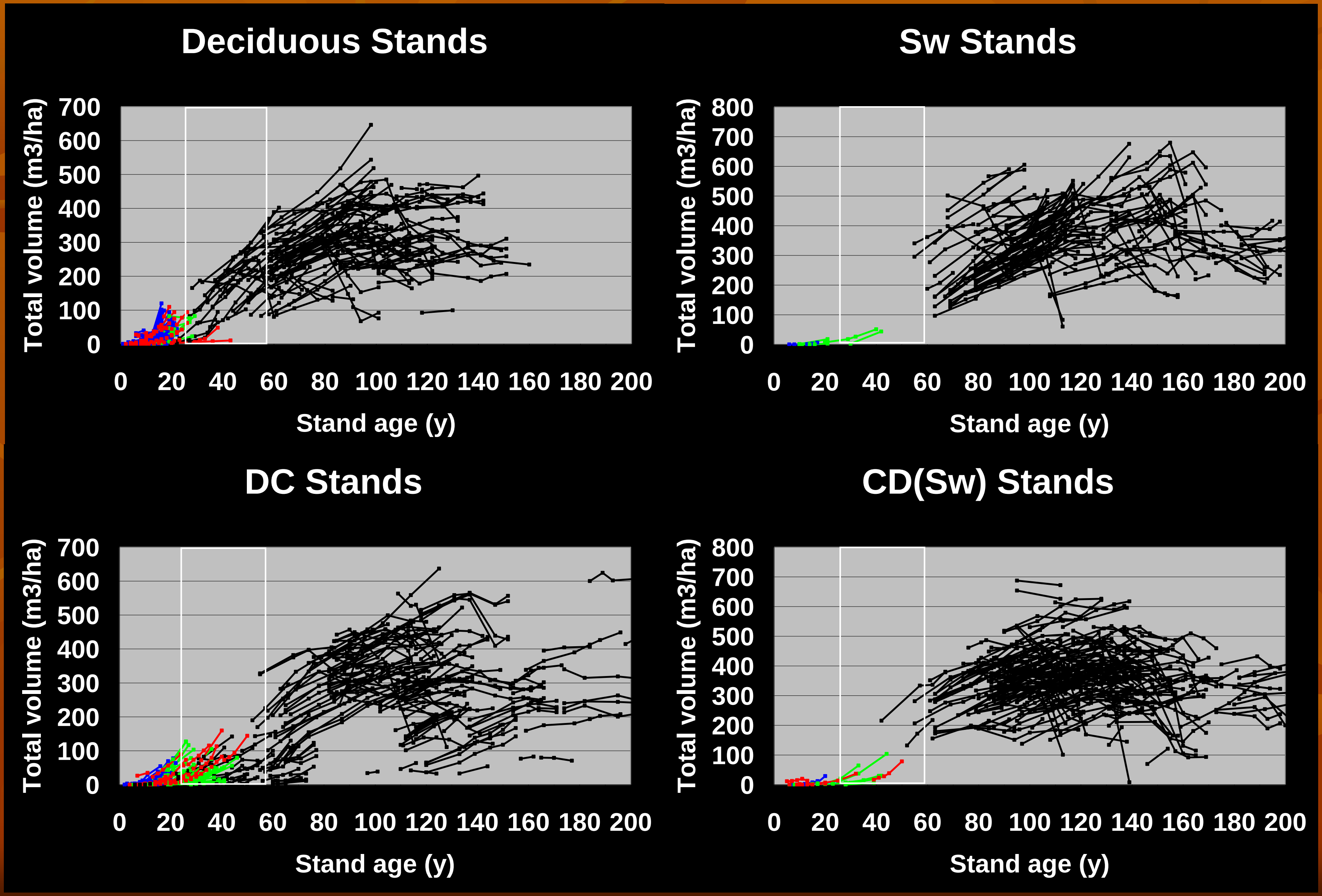


Data gap

Black = ASRD Mature PSPs (Natural stands)

Blue = ASRD SDS and MP (Regenerated)

Red, Green = Industrial regenerated PSPs



Modeling Silviculture, Forest Health and Genetics

Mixedwood Industrial Chair

- Boreal mixedwood modeling research
- Funding (2007 → 2011)
  - Forest Resource Improvement Association of Alberta
  - Mixedwood Management Association (MWMA)

Modeling early growth (establishment and performance)

Why model early growth?

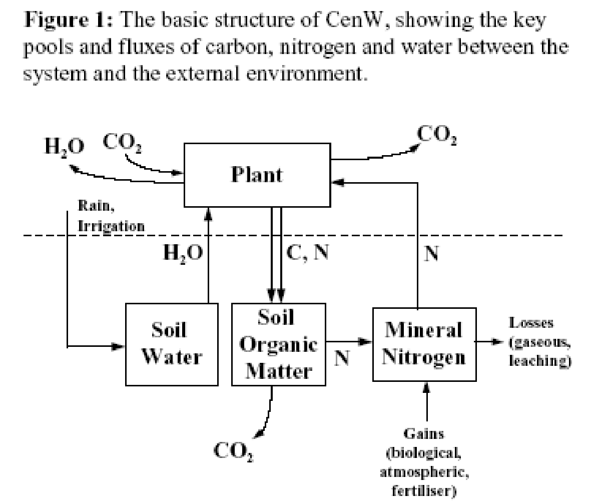
- Quantify growth and yield implications of establishment (msp, planting stock), brushing, herbicide, and PCT treatments
  - Program rationalization
  - Cost-benefit analysis
  - Performance
- Component of DFMP (Alberta Forest Management Planning Standard)
- Regeneration standards?

Why don't WE have an establishment-performance model?

- Hasn't been a priority
  - Yield modeling focused on older age classes
  - Silviculturists focused on their trees (establishment and tending issues, tools, techniques)

- It is a **COMPLEX** problem (multiple factors, hard to predict and control many of them, interactions abound)
  - Climate (long-term, year-to year variation)
  - Site (slope, aspect, soil, forest floor, ….)
  - Vegetation Development (species, rate of growth, time, cover)
  - MSP options
  - Stock types (health and vigor) – range of choices
  - Brushing and herbicide options – timing
  - Best growth of small conifers not always in "weed-free" (depends on limiting factors), importance of facilitation and competition vary with site,
- Limiting factors: light, soil temperature, soil moisture (flooding/drought), soil nutrients, competition (light, water, nutrients, space), chinook injury, summer frost, disease (root disease, gall rust), insects, ….

Models representing establishment and early performance response to silviculture (some recent examples)



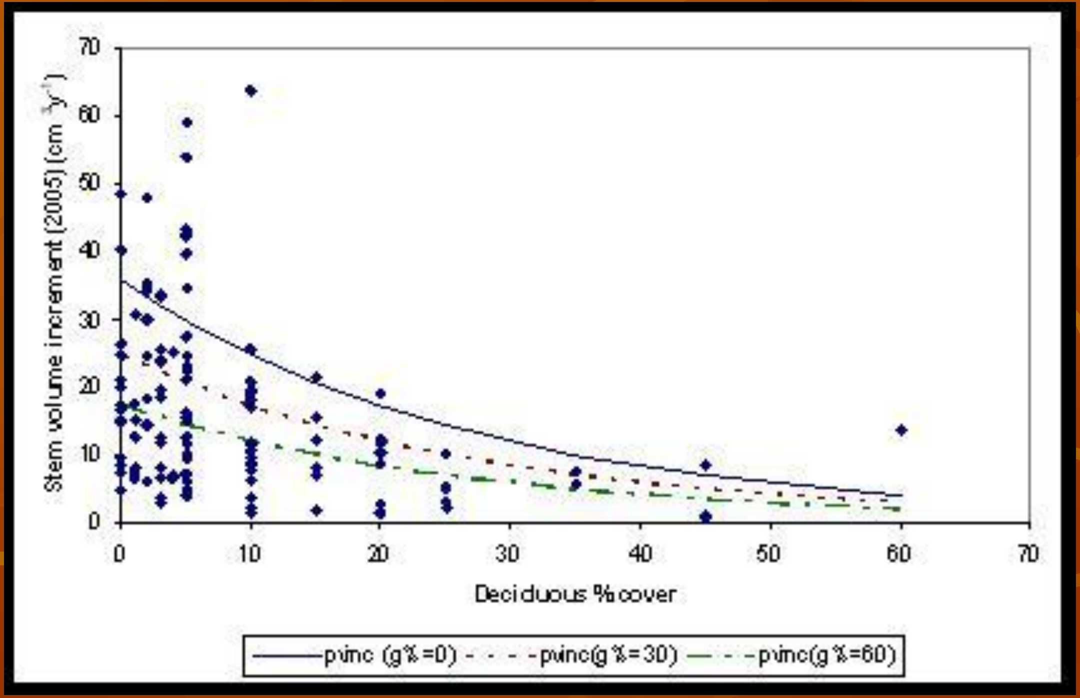
(Kirschbaum, 2005)

- RVMM (Steve Knowe)
  - Oregon, Wash., California
    - Douglas-fir
      - Empirical (Site, stock, veg. mgmt effects)
- VMAN – (Brian Richardson)
  - New Zealand
    - Radiata Pine
      - Empirical
- CONIFERS (Martin Ritchie)
  - California – competition for water
    - Conifers and broadleaves
      - Hybrid model (competition for water)
- “APAR” or C Budget models -Mason et al.
  - New Zealand
    - Radiata pine
      - Hybrid model (C budget approach)
- CenW - Miko Kirschbaum and Peter Sands (CSIRO)
  - Australia
    - Process (C budget approach)
- and others…

Where do we start?

- Modeling approach
  - Empirical?
  - Process?
  - Hybrid?
- Need to make best use of available knowledge
- Need to "represent" and be sensitive to limiting factors, treatments, major processes and interactions
  - Time step - ?hour; week?; month?; year?
  - Limiting factors: light, soil temperature, soil moisture (flooding/drought), soil nutrients, competition (light, water, nutrients, space), chinook injury, summer frost, disease (root disease, gall rust), insects, ….
  - Treatments – msp, brushing, spacing, herbicide.
- Challenges – stochastic events – frost, chinook injury, insects, drought… (need to understand probabilities and frequencies as well as impacts and responses)

Growth – competition relationships

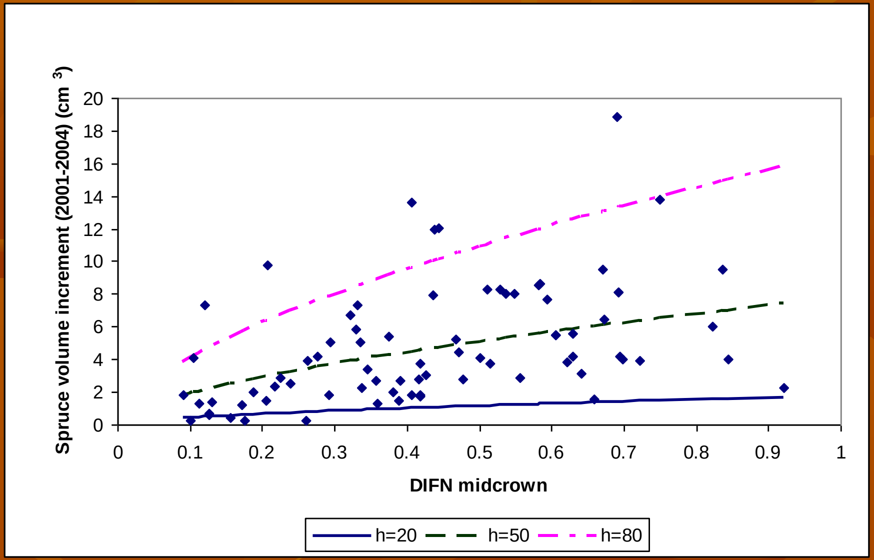


Relationship between stem volume increment of white spruce in 2005 and deciduous cover at Judy Creek. Lines are shown for three levels of grass cover (g% = 0, 30 and 60%) for the equation:

ln(VINC) = - 2.317 + 1.598 ln(HT2004) - 0.0369 dec% – 0.0121 grass%

(n=125 R^2adj=0.285 RMSE=0.752). Height 2004 = 40 cm for the lines shown.

Growth – Light – Cover/Basal Area



Relationship between volume increment (2001-2004) of white spruce and transmittance (difn-mid) at Mistahae.

$$VI=0.0137*ht^{1.621}*difn\text{-}mid^{0.6103}$$

($n=77$ $R^2=0.806$ $p<0.0001$).

Curves are shown for three levels of initial (2000) height (20, 50, and 80 cm).

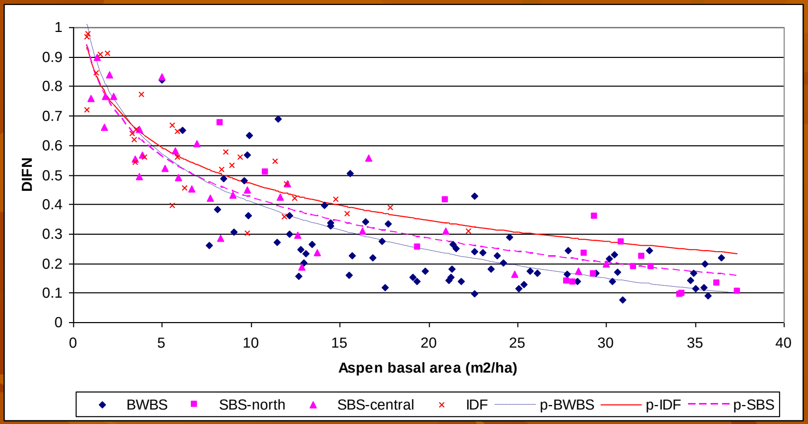
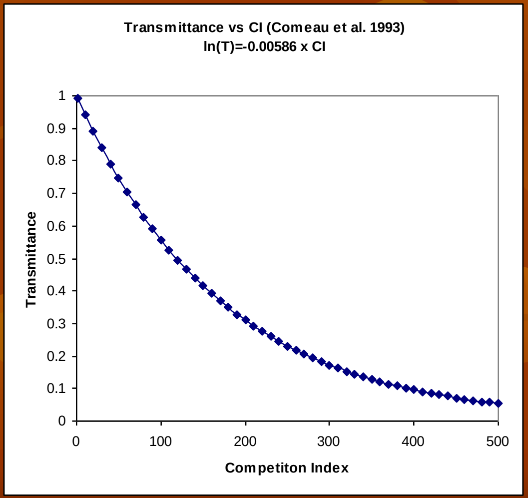


Figure 1. Scatter plot showing the relationship between understory light (difn) and aspen basal area (BA_A). The dashed blue line (p-BWBS) illustrates the regression fit to data from the BWBS and is described by the equation: $difn=0.9492-0.2352\ln(BA_A)$ ($n=68$; $R^2=0.534$; $RMSE=0.1052$). The red line (p-IDF) shows the line developed for the IDF stands and is described by the equation: $difn=0.8802-0.1781\ln(BA_A)$ ($n=30$ $R^2=0.779$; $RMSE=0.0924$). The dashed mauve line shows the line fit to data from the SBS (p-SBS) and is described by the equation $difn=0.833-0.2004\ln(BA_A)$ ($n=48$ $R^2=0.808$; $RMSE=0.1007$).



Understory light levels change during the growing season, depending on overstory species and cover.

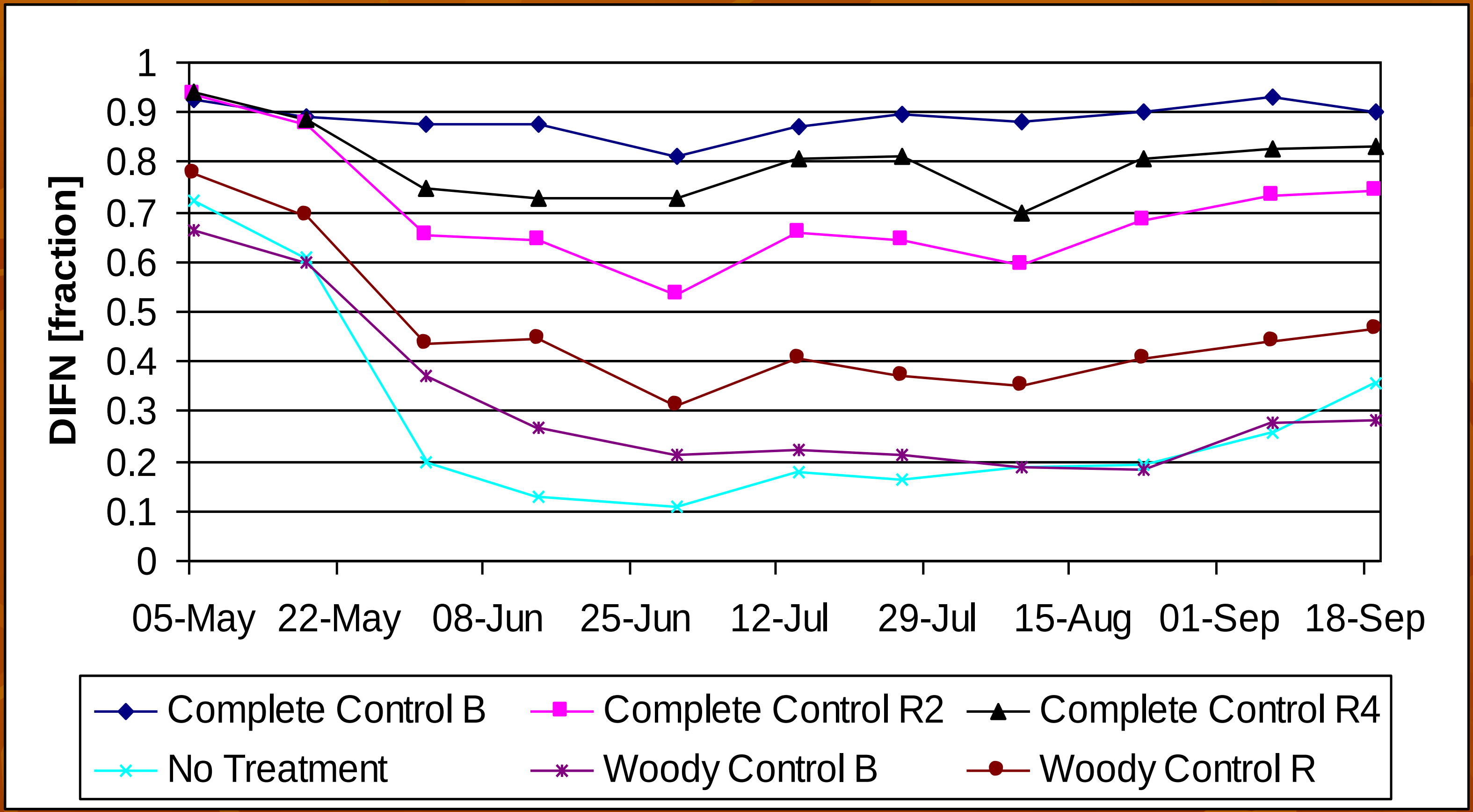
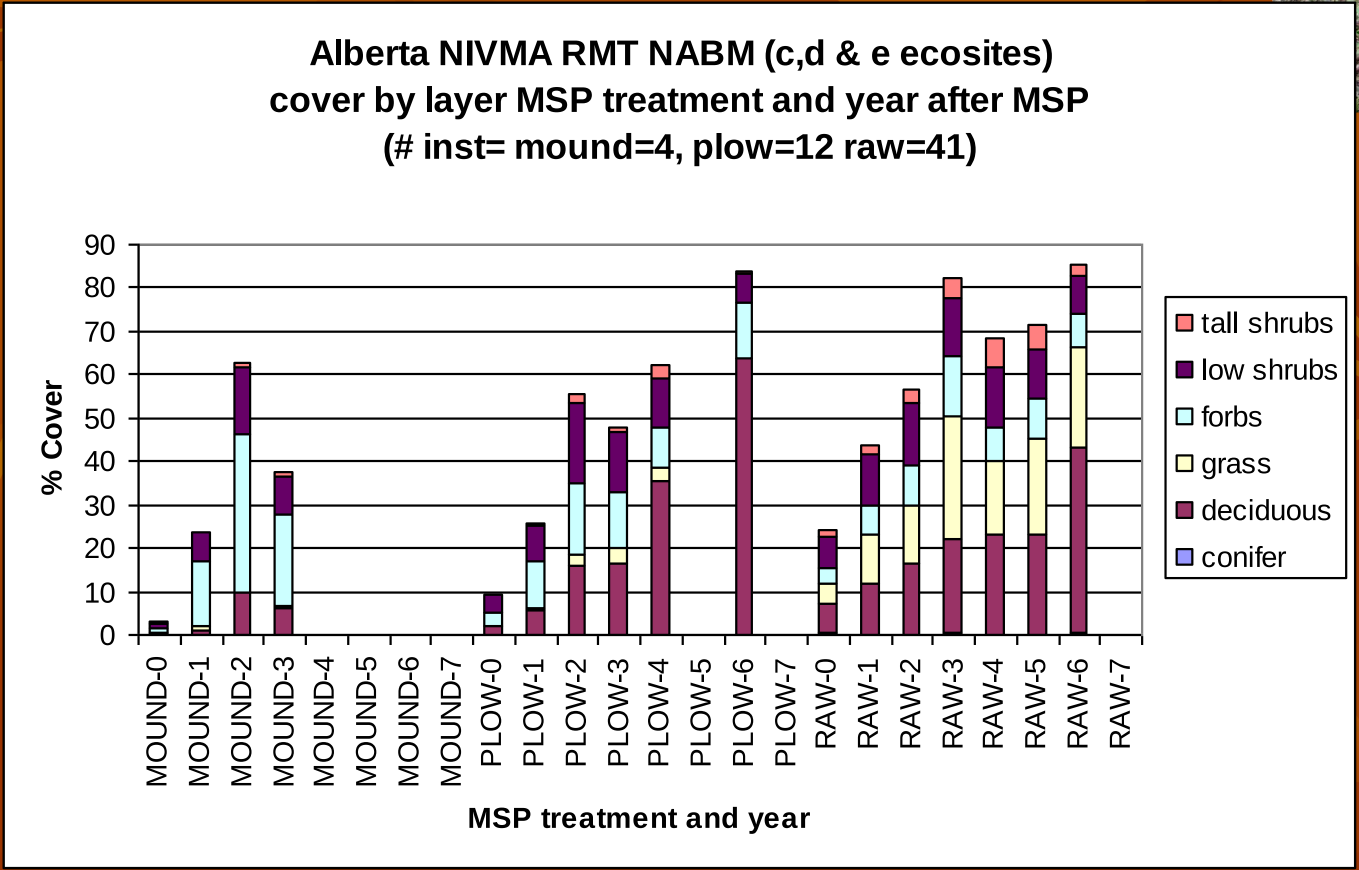


Figure 3.25. Light (DIFN) seasonal trends during the growing season of 2005 (May 03 – September 19). B – Broadcast; R2 – radial 2 years control; R4 – radial 4 years control.

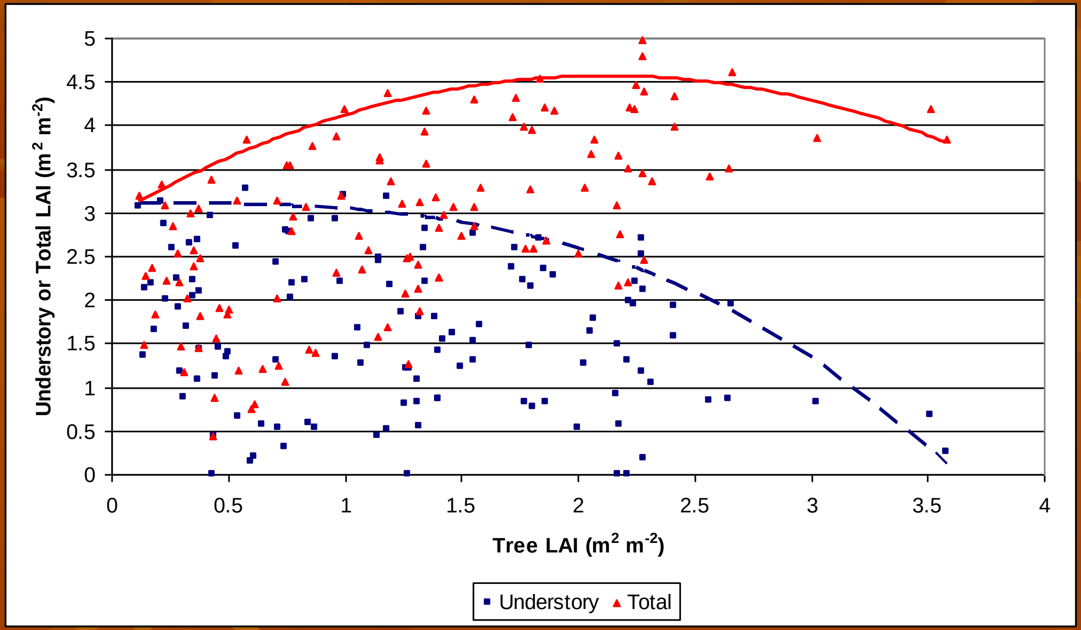
Cosmin Man (M.Sc. in prep)

Cover development



Need to represent effects of overstory (aspen, spruce and pine) on understory LAI or cover

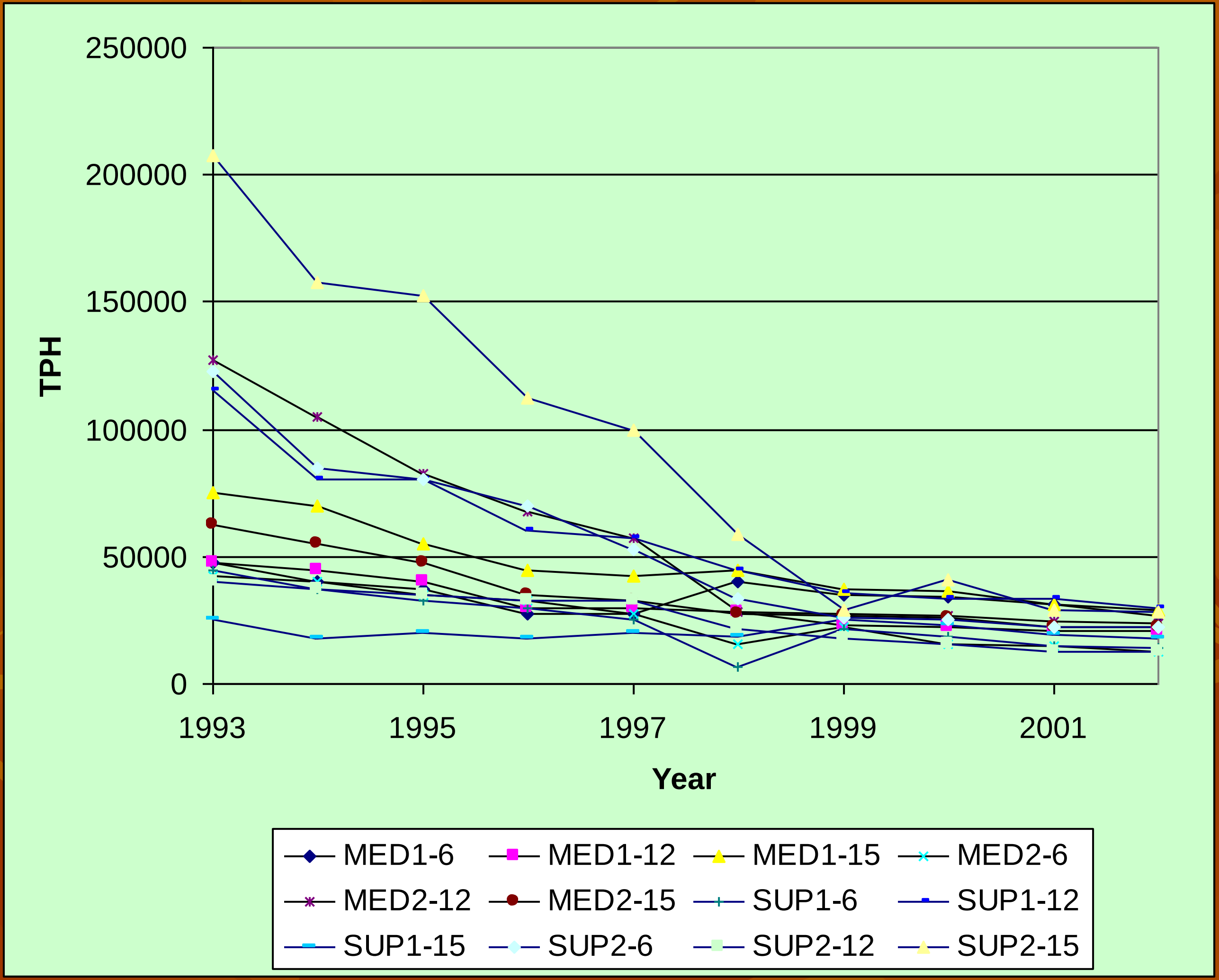
Relationships between aspen and understory LAI in a 12 year old stand



- The lines shown were fit to the upper 10% of data points in each of 7 classes of tree LAI and are described by the equations:
- $LAIU = 3.1095 - 0.06524*LAIO^3$
- $LAIT = 2.9531 + 1.5207*LAIO - 0.3586*LAIO^2$.

Intraspecific competiton and self-thinning

Changes in aspen density during first 11 years



Data from WESBOGY Long-Term Study – DMI Installations

"SPRUCE" – model concept (Comeau)

- Model for establishment and growth of white spruce in western boreal forests
- Represent effects of site factors, site preparation, stock type, vegetation management, and precommercial thinning.
- Hybrid model (individual tree, distance independent(?))
  - **Grow** spruce, aspen, shrubs, forbs and grasses (interacting)
  - Link to **ecosite specific** empirical growth data
  - **"C" budget model** – on an hourly or daily time step to represent effects of factors (calculate growth "adjustments").
  - **Factors**: Climate, site, and competition effects on –
    - Light, soil temperature, soil moisture, N, air temperatures – model on hourly(?) time steps.
    - Chinook and frost injury – risk and frequency need to be worked out, risk factors need to be better understood, injury response needs to be separated from other factors
  - **Treatment effects** – modeled through influences on limiting factors with representation of regrowth of vegetation – (need some spatial representation of microsite and proximity of vegetation and aspen)

Conclusions

- Modeling establishment and performance is a complex problem
- Unlikely we can use an existing model– but we can learn from other models
- Models need to be structured to transfer tree lists or link to G&Y models
- Hybrid models may provide the most flexible option and allow use of both data and understanding.
  - Opportunity – to link data and knowledge
  - Additional data and research is needed to fill gaps
  - **WE NEED REAL DATA** for trees and all other vegetation from well documented remeasured plots - For parameterization and validation.
- Model development can help to focus and direct research

Type I and II responses

- Type I – differences related primarily to speeding up initial development – curves parallel at mid-age and converge over time
- Type II – sustained increases in volume (often diverging growth curves during mid-age) reflecting better site quality or site utilization by the "crop" species
- But which is it???