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Error Propagation in Forest Planning Models

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Outline

- Measurement errors
- Characterization of errors
- Traditional Methods
- Two Stage Error Distribution (TSED) method
- Case Study in error propagation
- Discussion of results

Measurement Error (ME) in Forestry

- Arises when there is a difference between observed and actual value for an attribute
  - Sampling error (only portion of population measured)
  - Grouping error (model calibrated to one level of precision and then applied to a different one)
  - Mensuration error (a flaw in the measurement process)

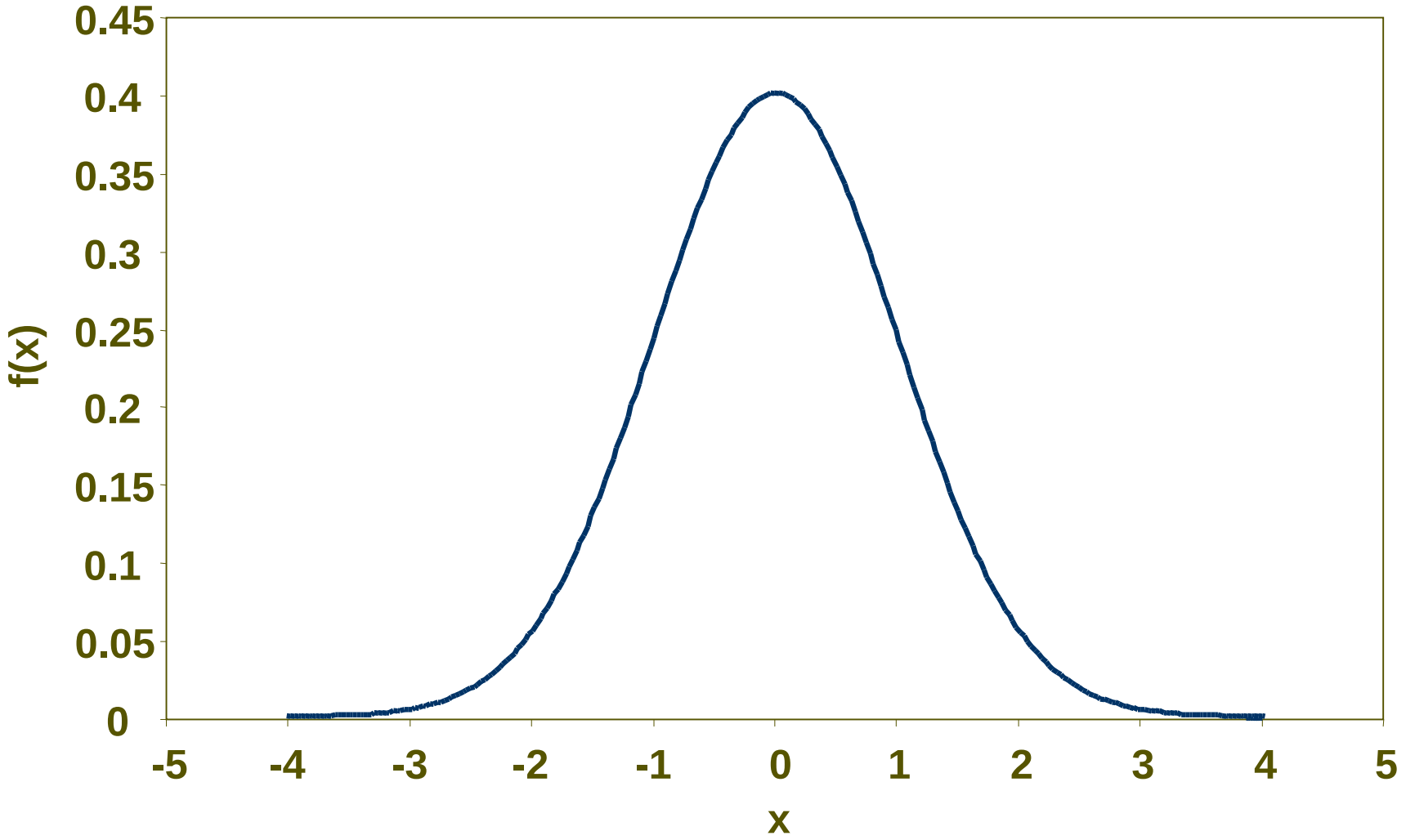
Measurement Error (ME) in Forestry

- Demonstrated Consequences:
  - Biased estimates of tree and stand attributes
  - Biased model parameters and predictions
  - Decreased precision of model predictions
  - Heteroskedastic prediction errors
  - Skewed distributions
  - Biased fit statistics

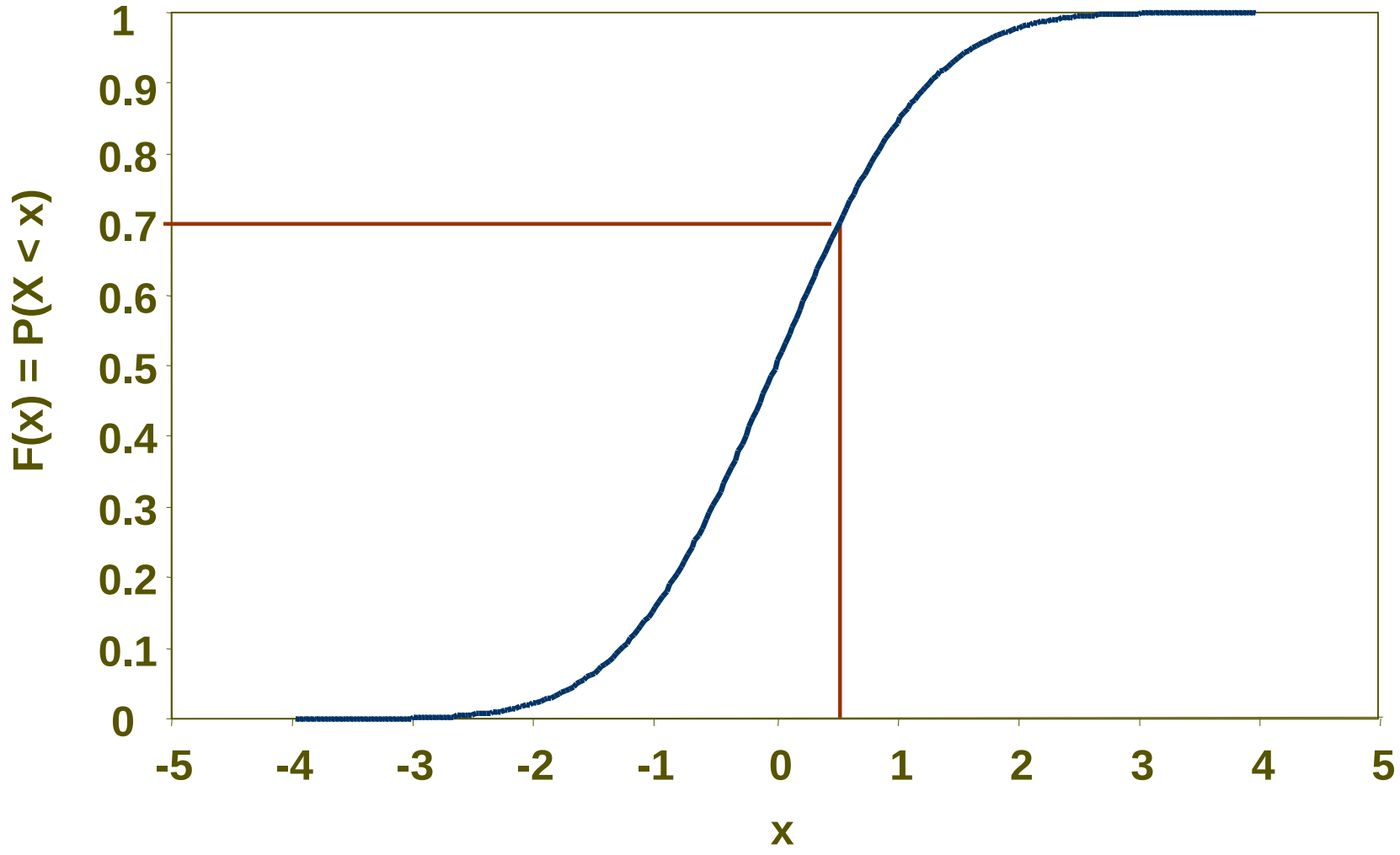
Measurement Error (ME) in Forestry

- Distribution of errors provides the means for evaluation and possible correction methods
- Specified by either:
  - Probability distribution function (PDF) or,
  - Cumulative distribution function (CDF)

Normal (0,1) PDF



Normal (O,1) CDF



Traditional Methods

- Errors assumed to be normally distributed
  - Assume $\mu(\delta_x) = 0$
  - Assume $\mu(\delta_x) =$ constant other than 0
  - Assume $\mu(\delta_x) = f(x)$
- In turn each of these separated by
  - Assume $\sigma(\delta_x) =$ constant
  - Assume $\sigma(\delta_x) =$ variable

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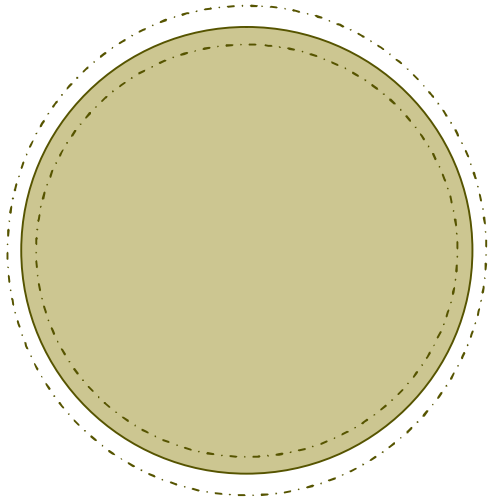
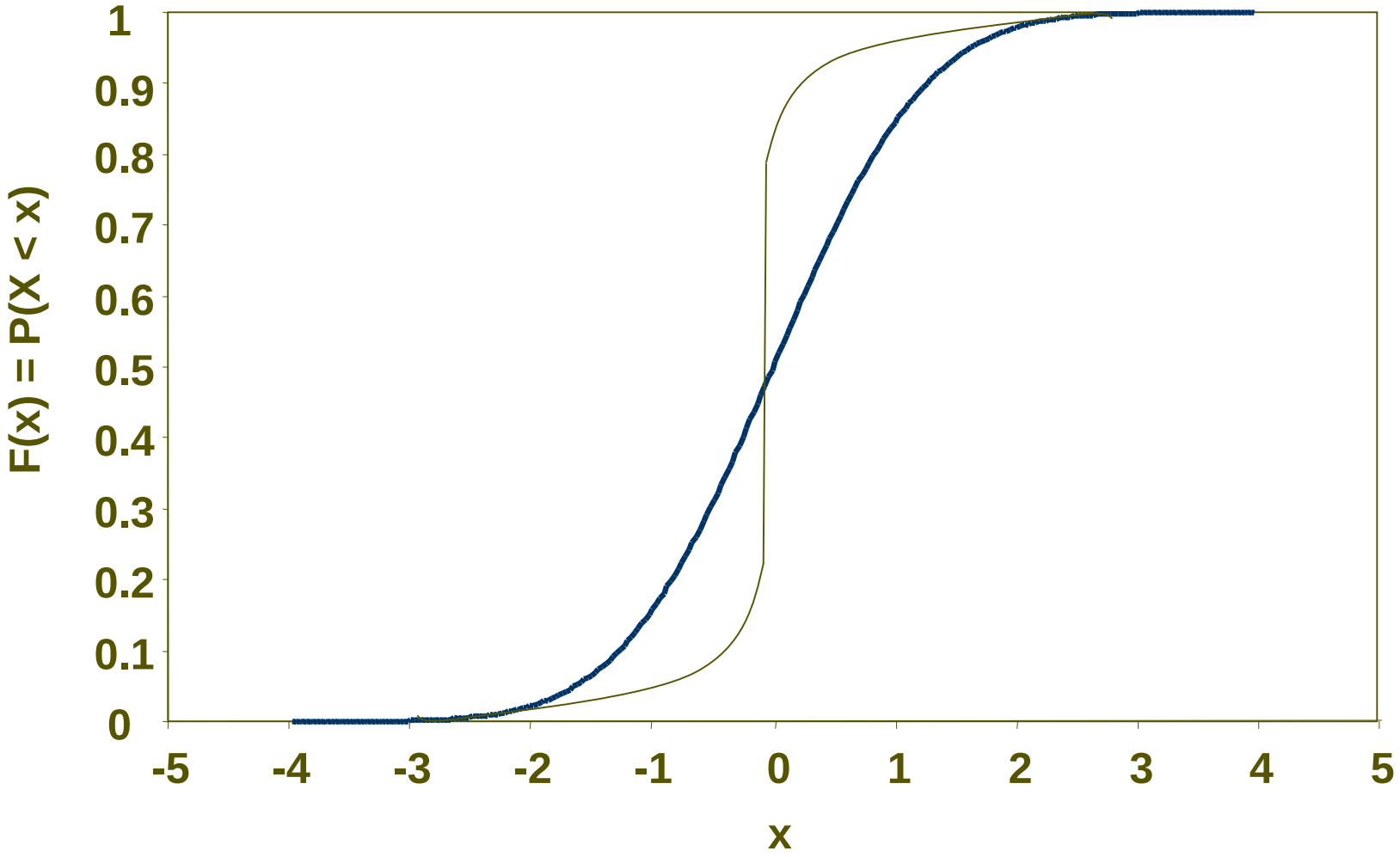
Traditional Methods

- Unbiased error doesn't necessarily average out
  - Basal area example
    - 20 cm tree, 314.16 cm^2
    - 0.5 over, 330.06 cm^2
    - 0.5 under, 298.65 cm^2
  - Average = 314.56 cm^2
- Normal easy to model
  - Is it appropriate choice?



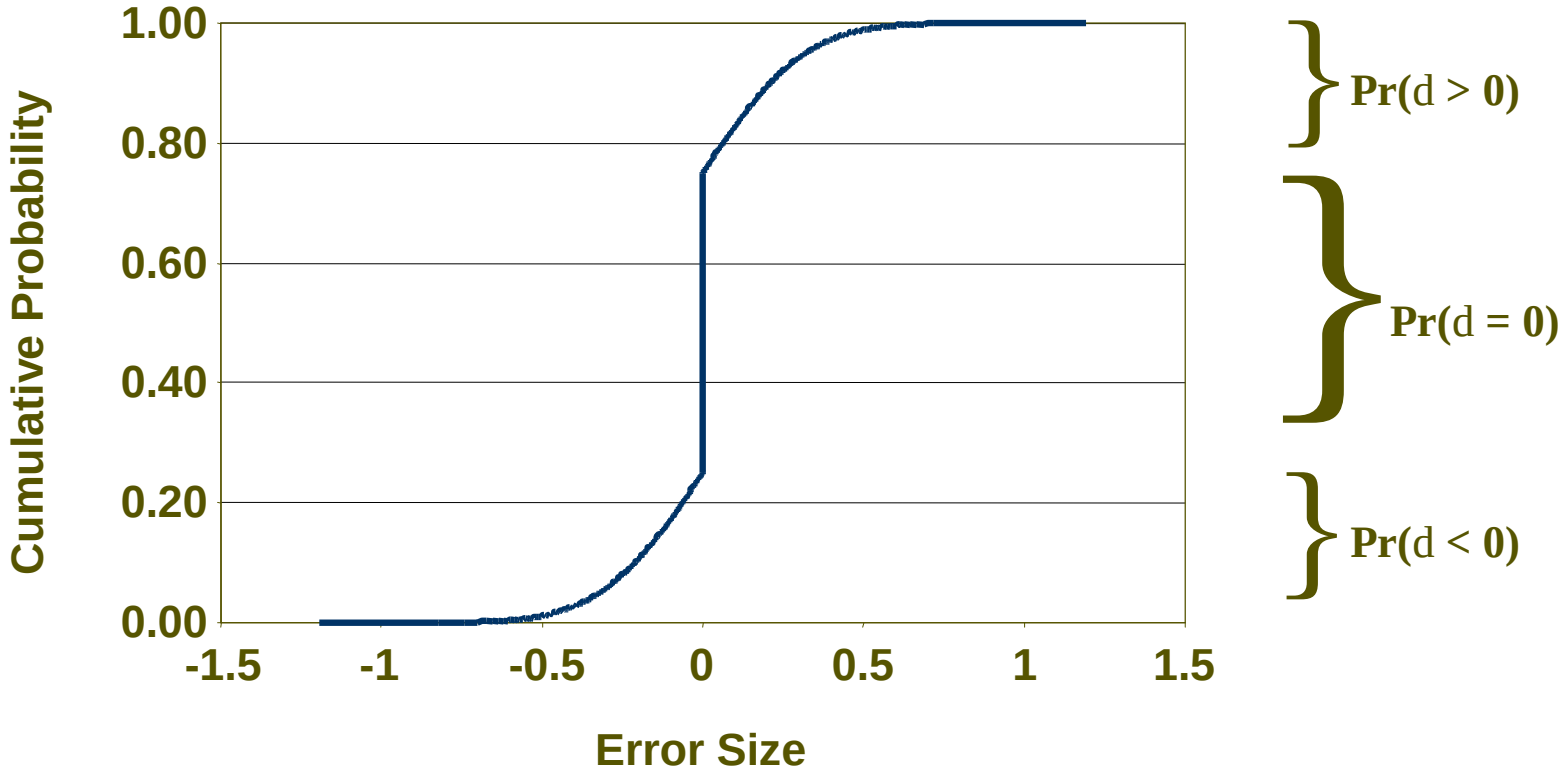
Normal (O,1) CDF



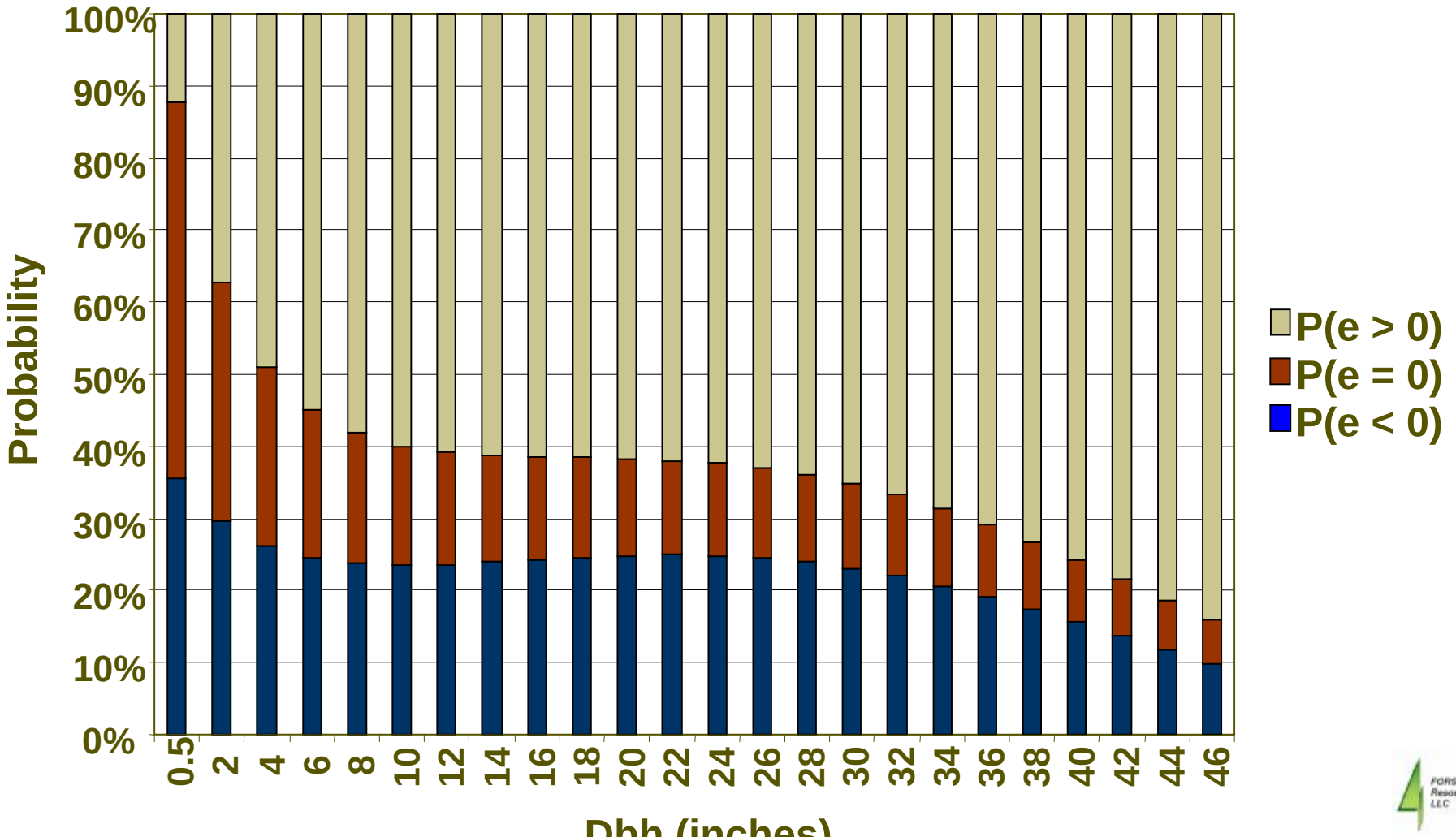
Fitted CDF Equation

$$P(X = x) =$$

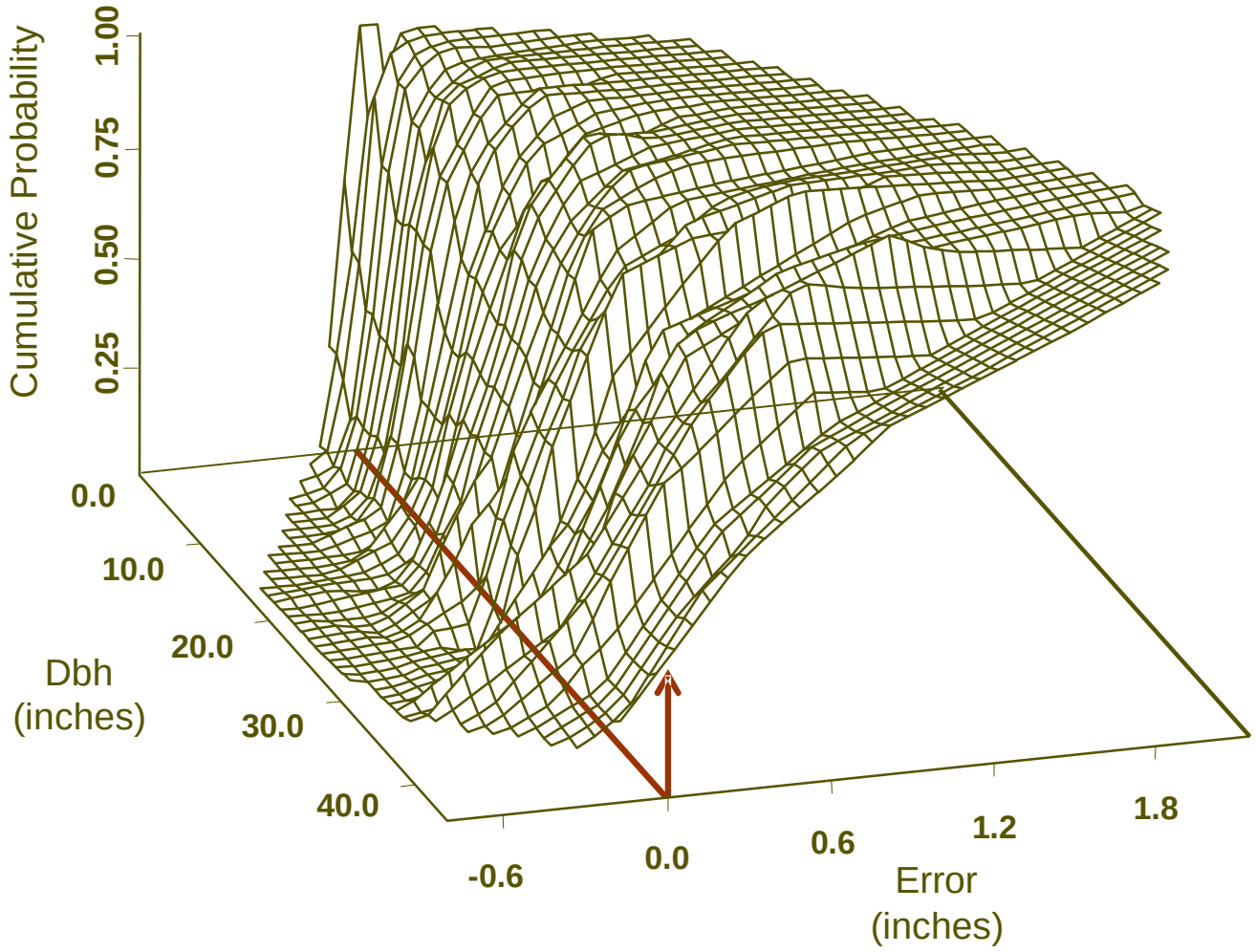
Pr(d < 0)*Negative Error CDF	d < **0**
Pr(d < 0) + Pr(d = 0)	d = **0**
Pr(d < 0) + Pr(d = 0) + Pr(d > 0)*Positive Error CDF	d > **0**



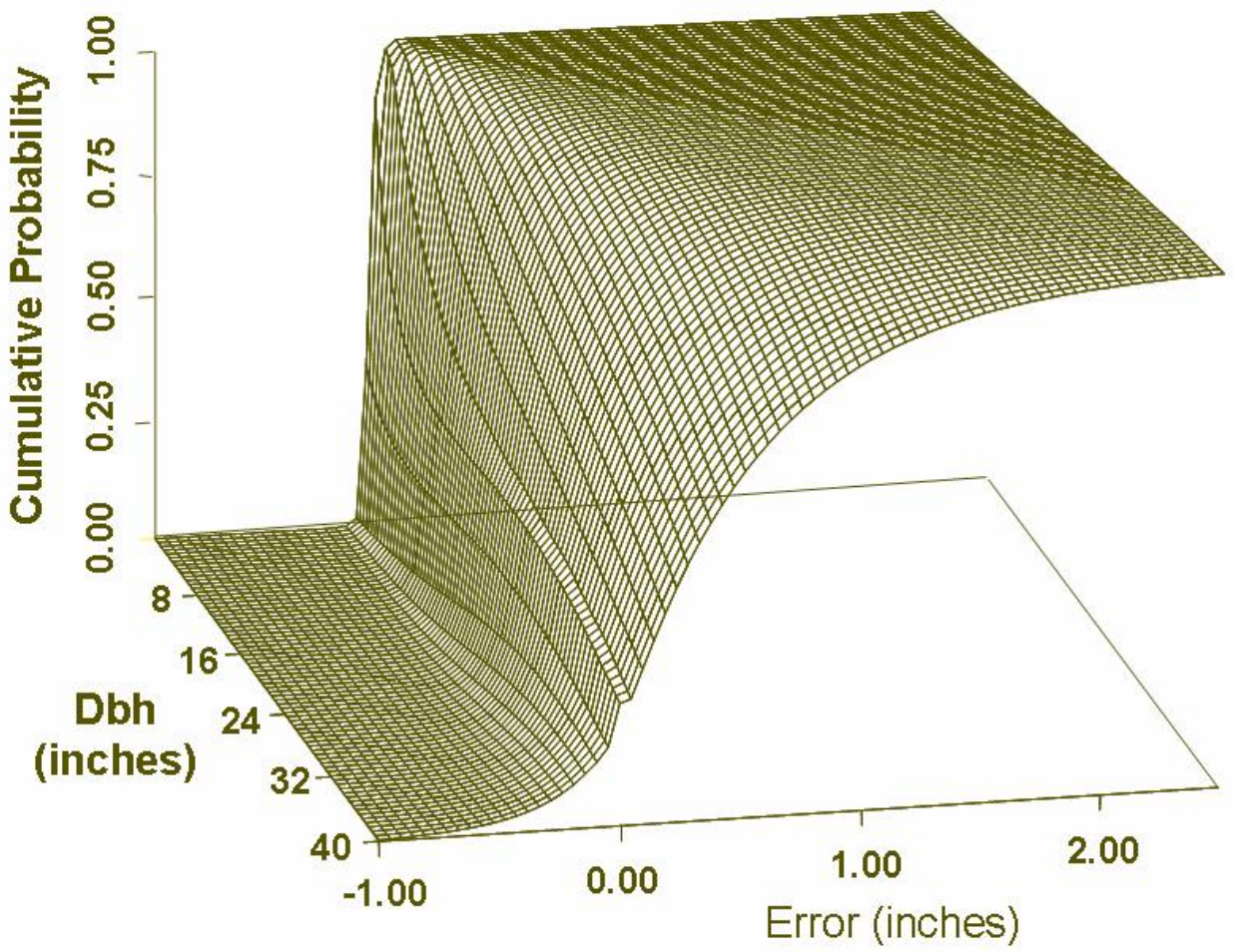
Fits of Error Type Probabilities



Empirical Dbh Error CDF Surface



Fitted Dbh CDF Surface



Forest Modeling Experiment

- Inventory data (tree lists) from PNW covering a range of forest types
- Apply corrections to measured dbh and ht derived from TSED analysis
  - None, dbh only, ht only, dbh & ht
- Project growth through Organon
- Use yield tables in mock forest planning exercise for a TIMO client

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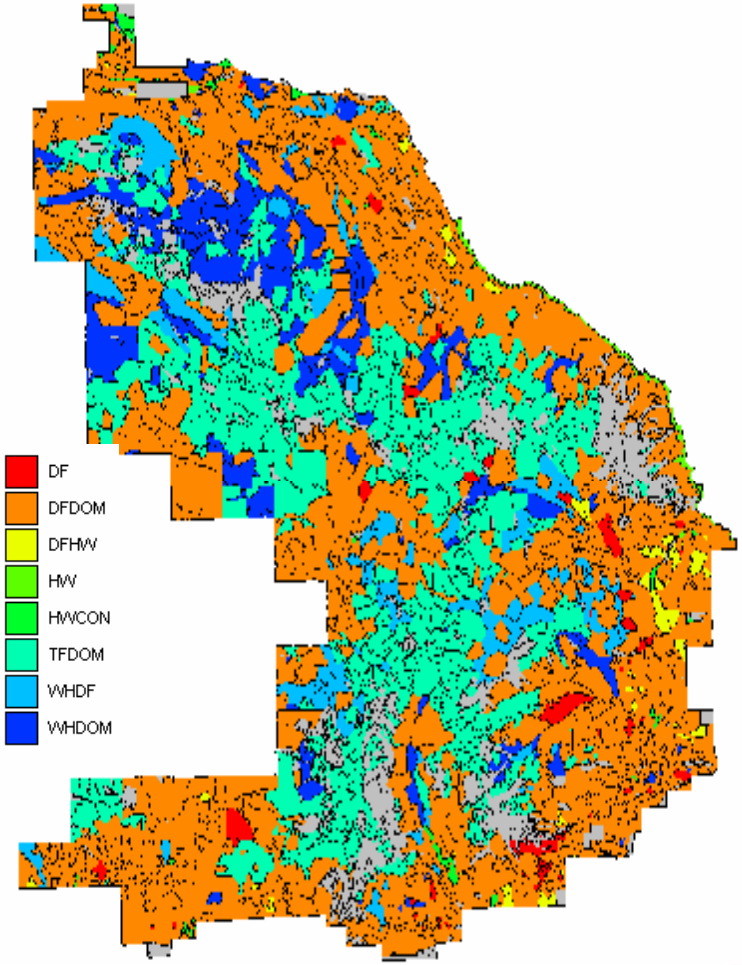
Example Forest

- Southwest Washington
- 69,000+ ac
- Species group(8), site (3),BA(4),stocking(3)
- Elevation(3),slope(3), operability(2)
- Regen(2spX2dens), PCT(4), fert, CT(2), prune



Model Parameters

- NPV maximization (pseudo-delivered price)
  - Delivered prices for 10 products
  - Average logging costs ($/mbf) by equipment type, average hauling cost ($/mbf)
  - Road const & maint ($/mbf), sev. taxes ($/mbf)
- 5-yr planning periods
- 30 period planning horizon

Unconstrained

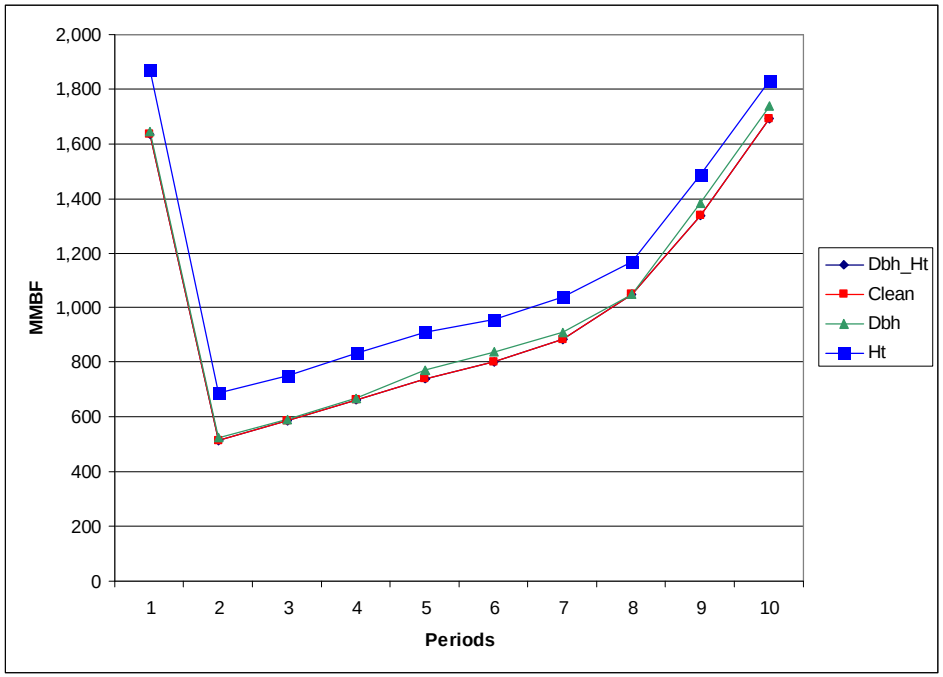
- Any differences due to yield coefficients
- Not confounded by constraints

Unconstrained

- Base solution = Dbh_Ht errors present
- Present Net Value
  - Ht_err (dbh corrected)= 1.61% higher
  - Dbh_err (ht corrected)= 2.85% higher
  - Clean (dbh & ht corrected)= 2.04% higher

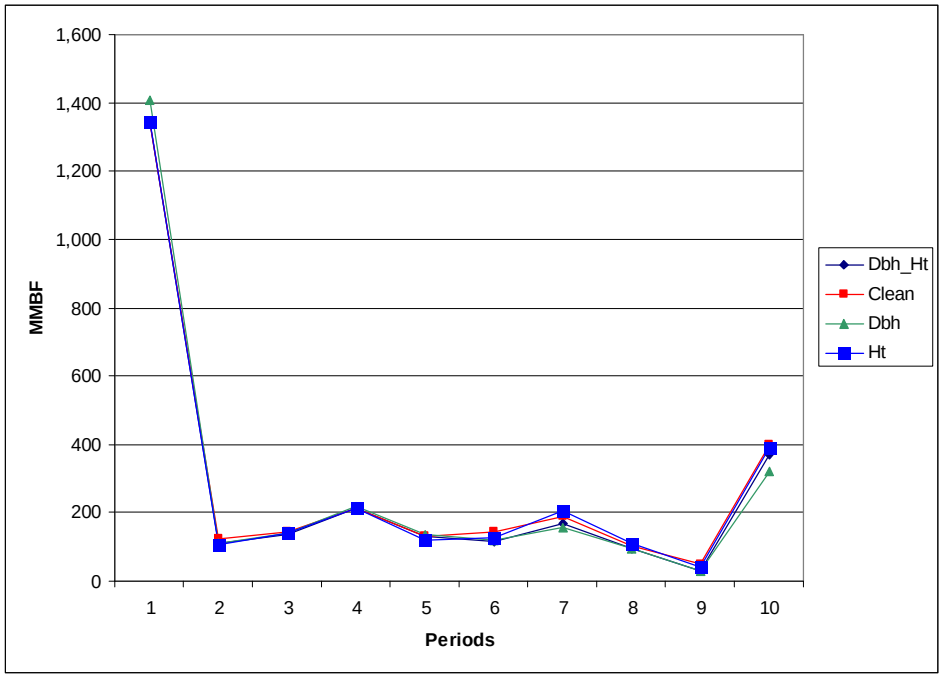
Unconstrained

- Initial Inventory
  - Ht_err 14.4% higher
  - Dbh_err < 0.43% high
  - Clean = Dbh_Ht_err
- All periods
  - Ht_err always significantly higher



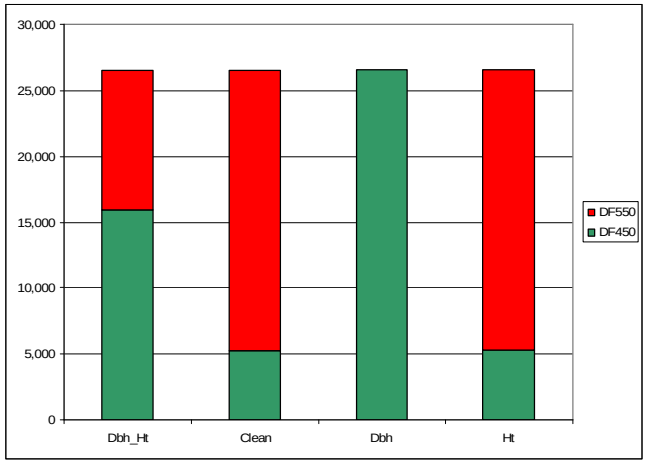
Unconstrained

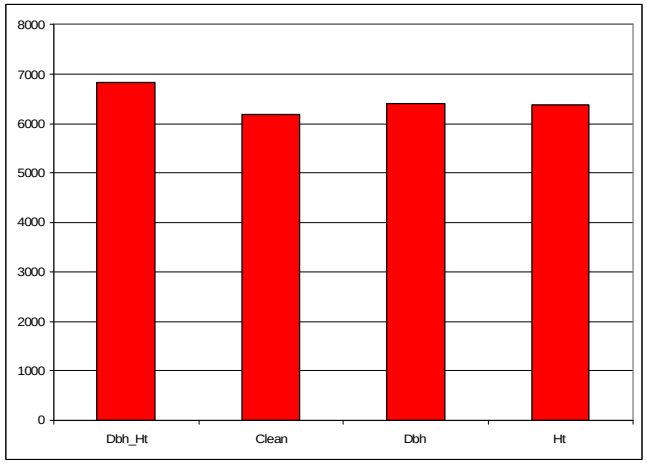
- Period 1 Harvest
  - Dbh_err 5.00% higher
  - Ht_err 0.52% higher
  - Clean 0.01% higher
- First 10 periods
  - Dbh_err 1.00% higher
  - Ht_err 3.76% higher
  - Clean 4.84% higher



Unconstrained

- Period 1 regeneration
  - Dbh_err plants only DF450
  - Clean & Ht_err plant far more DF550
- Period 1 thinning
  - Dbh_err 6.36% less
  - Ht_err 6.50% less
  - Clean 9.48% less





Sequential Control

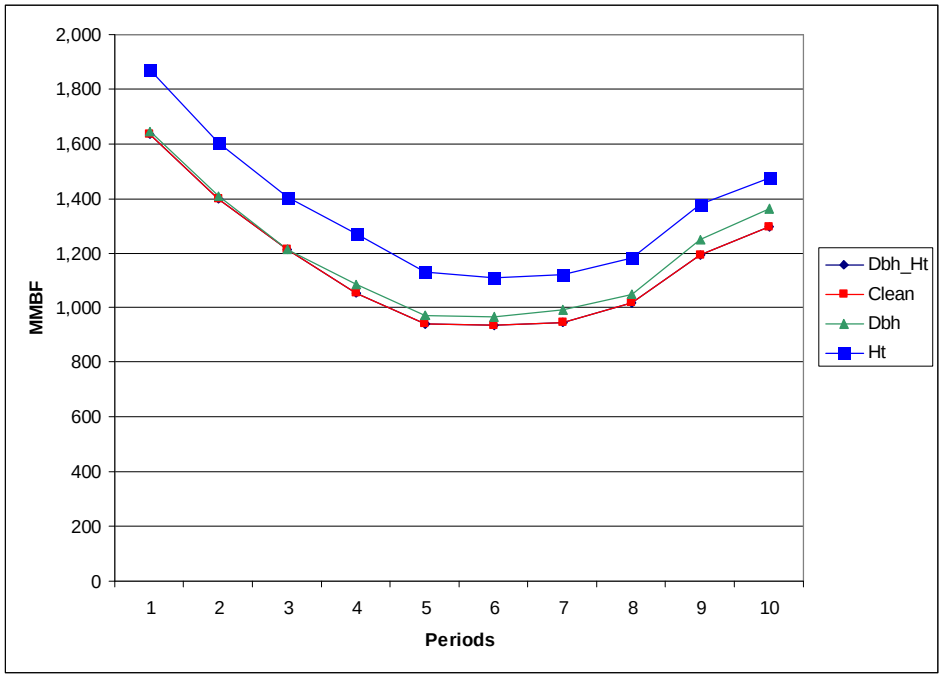
- +/- 10% sequential flow on harvest acres
- Smooths volume and revenue spikes

Constrained

- Present Net Value
  - Ht_err (dbh corrected)= 1.33% higher
  - Dbh_err (ht corrected)= 2.93% higher
  - Clean (dbh & ht corrected)= 3.43% higher

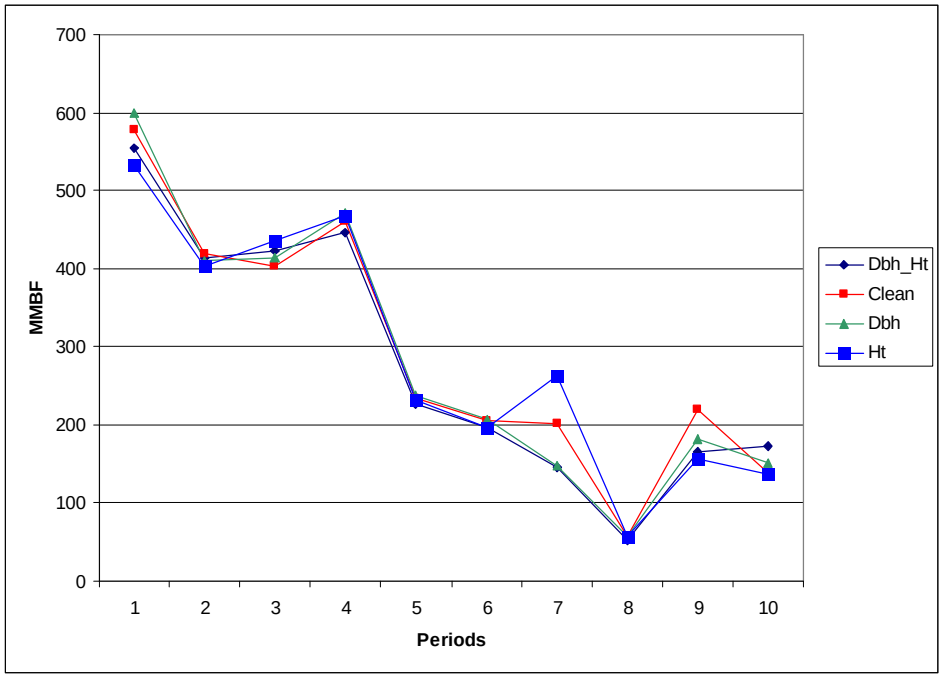
Sequential Control

- Inventory
  - Ht Err always has highest inventory



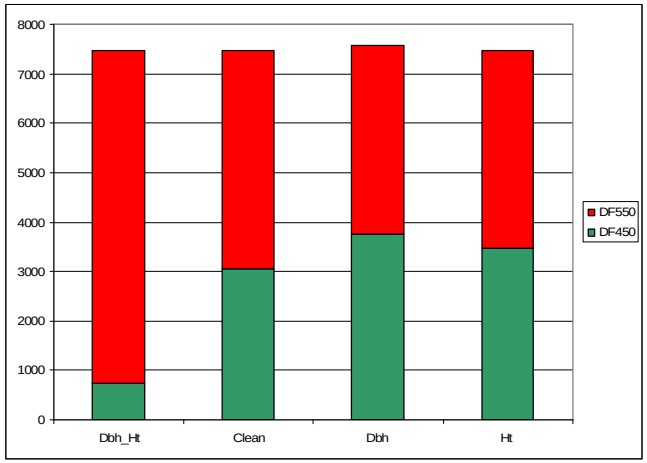
Sequential Control

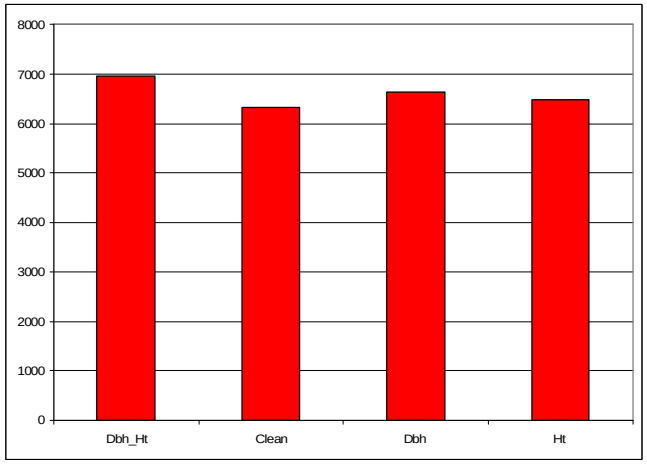
- Period 1 Harvest
  - Dbh Err 8.04% higher
  - Ht Err 3.97% lower
  - Clean 4.41% higher
- 10 Period Harvest
  - Dbh Err 3.04% lower
  - Ht Err 3.00% higher
  - Clean 4.54% higher



Sequential Control

- Period 1 regeneration
  - All far more DF450
  - Dbh_err highest DF450
- Period 1 thinning
  - All perform less CT
  - Clean does least





Discussion - Unconstrained

- Initial inventory varies by as much as 14%
  - Nightmare scenario in acquisition due diligence
- PNV over 2% higher with cleaned yields
- Silviculture significantly different
  - Clean run plants much more DF550 in period 1
  - Clean thins almost 10% fewer acres in period 1
  - Clean produced ~5% more volume over 50 yrs

Discussion – Constrained

- Flow constraint created bigger differences
  - More variation in the harvest sequence
  - Significant differences in silvicultural regimes
  - Even more variation in PNV

Discussion

- Measurement errors
  - Conventional wisdom assumes MEs cancel out over the long run… *NOT TRUE!!!*
  - Effects are apparent immediately
    - Not limited to small, consistent variation
  - Can pronounce differences in merchandising
    - Log length is becoming the dominant parameter in price determination

Discussion

- Optimization models can amplify ME effects
  - Sensitive to prices tied to yields
  - Tries to capitalize on erroneous differences in yield to maximize revenue
  - Inappropriate silvicultural regimes chosen
- Not only objective function is changed
  - Timing and activities also changed
  - Plan is off-track and analysis becomes suspect

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Thank you.

Any questions?