A Comparison of Alternative Data Sources for Modeling Site Index in Loblolly Pine Plantations

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Data Types

- Permanent plot
- Stem analysis
- Temporary plot

Data Description

- 186 Permanent plots
  - 3 Subplots: Control, Light thin (30% BA removed), Heavy thin (50% BA removed)
  - Measured on 3-year cycle for 21 year period
  - 822 height-age observations
  - Initial age range: 8 to 25 years
- Stem Analysis
  - One dominant and one codominant tree selected at time of plot establishment (trees felled in thinned plots)
  - Height-age pairs calculated from ring counts taken at 4-foot intervals
  - 372 trees, 3794 height-age observations
- Temporary plots
  - 186 height- age observations from 1st measurement in permanent plots

Research Question

- How do site index curves constructed from stem analysis and temporary plot data perform for depicting future dominant height development as compared to curves developed from permanent plot data
  - Use same model form to guard against confounding
- Determine optimal number of measurements in permanent plots to produce accurate height-age equations

Models: Dominant Height Prediction

- Chapman-Richards

$$H_{d,i} = \beta_1 * [1 - \exp(-\beta_2 * A_i)]^{\beta_3} + \varepsilon_i$$

- Schumacher

$$H_{d,i} = \beta_1 * \exp\left(-\beta_2 * A_i^{-1}\right) + \varepsilon_i$$

- $H_{d,i}$ = dominant height (meters) of plot *i*
- A_i = stand age (years) for plot *i*
- β_k = parameters to be estimated
- ε_i = random error

Models: Dominant Height Projection

- Chapman-Richards

$$H_{d2,i} = H_{d1,i} * \left[\frac{1-\exp(-\beta_2 * A_{2,i})}{1-\exp(-\beta_2 * A_{1,i})}\right]^{\beta_3} + \varepsilon_i$$

- Schumacher

$$H_{d2,i} = H_{d1,i} * \exp\left(-\beta_2 * \left(A_{2,i}^{-1} - A_{1,i}^{-1}\right)\right) + \varepsilon_i$$

- $H_{d1,i}$ = dominant stand height (meters) at plot age one $A_{1,i}$ (years)
- $H_{d2,i}$ = dominant stand height (meters) at plot age two $A_{2,i}$ (years)
- Other variables defined as before

Determining optimal number of measurements for permanent plots

- A subset of the permanent plot data were selected to include only plots that had at least six measurements
- Dominant height projection models were fit separately with 2, 3, 4, 5, and 6 measurements, yielding five sets of parameter estimates for each model
- Procedure ensures that any improvement in model performance is to due added information from additional measurements
- Models evaluated on ability to predict dominant stand height
- Site Index curves constructed to examine how change in parameter estimates due to additional measurements effect curves

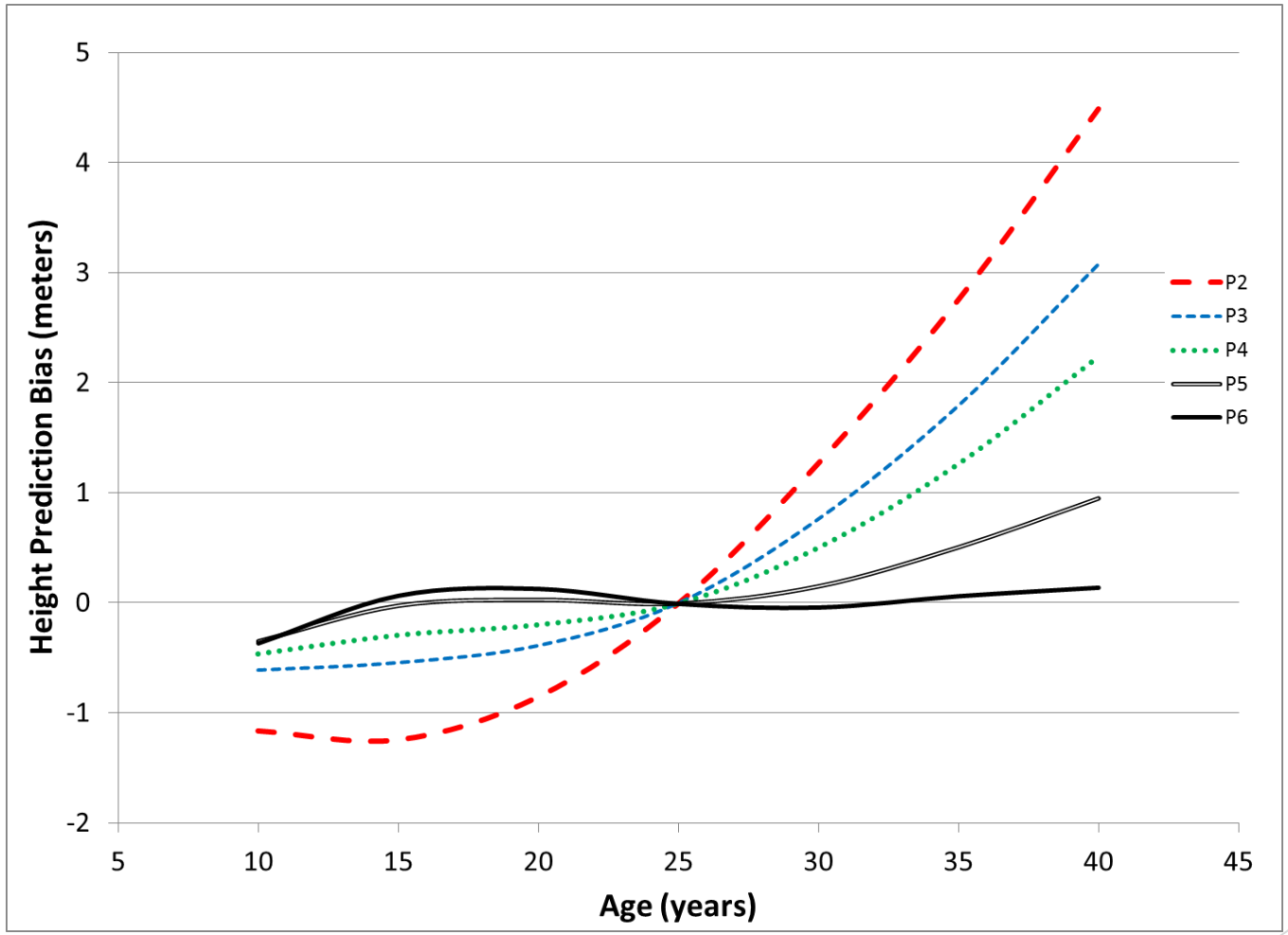
Parameter Estimates

Model	β_2	β_3	SE β_2	SE β_3
Chapman-Richards				
P2	0.1056	1.8384	0.0139	0.2208
P3	0.0715	1.4440	0.0084	0.1129
P4	0.0557	1.2740	0.0062	0.0783
P5	0.0346	1.0687	0.0052	0.0580
P6	0.0216	0.9488	0.0045	0.0469
Schumacher				
P2	10.8556		0.3297	
P3	11.6306		0.2407	
P4	12.1201		0.2115	
P5	12.7490		0.2163	
P6	13.2416		0.2224	

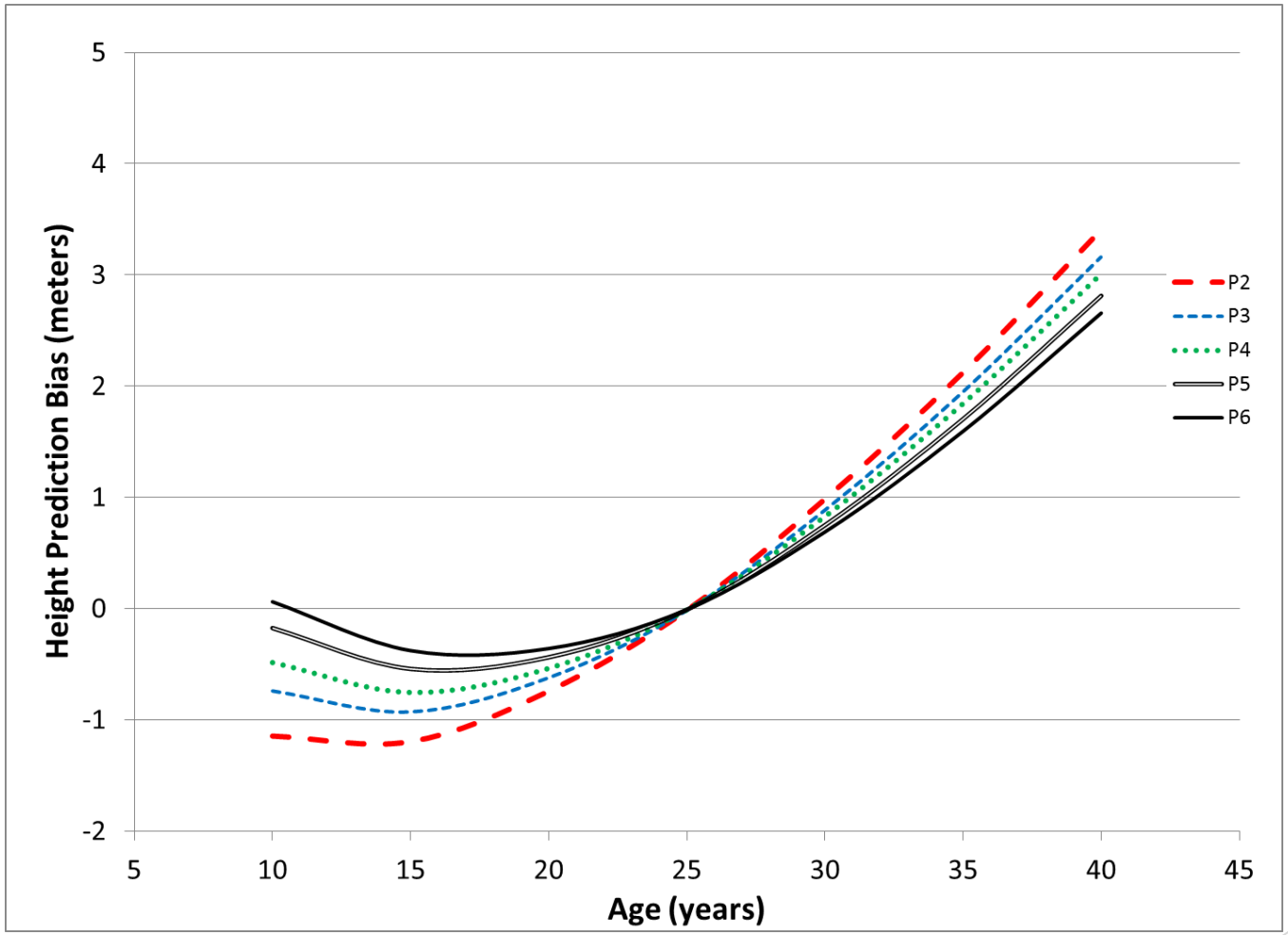
Dominant height prediction bias (Observed – Predicted) (Meters)

Model	Abs Mean	Mean	St Dev	Min	Max
Chapman-Richards					
P2	1.1435	0.0180	1.5574	-3.8363	7.2576
P3	0.7334	0.1026	1.0792	-3.0709	5.8681
P4	0.6017	0.1009	0.8907	-2.7955	4.9964
P5	0.5082	0.0623	0.7301	-2.5063	3.7352
P6	0.5021	0.0142	0.7143	-2.8986	3.2758
Schumacher					
P2	0.9857	-0.0657	1.3307	-3.7859	6.0789
P3	0.8600	0.0075	1.2019	-3.4902	5.8461
P4	0.7895	0.0523	1.1273	-3.3066	5.6974
P5	0.7142	0.1083	1.0404	-3.0742	5.5045
P6	0.6693	0.1510	0.9804	-2.8949	5.3518

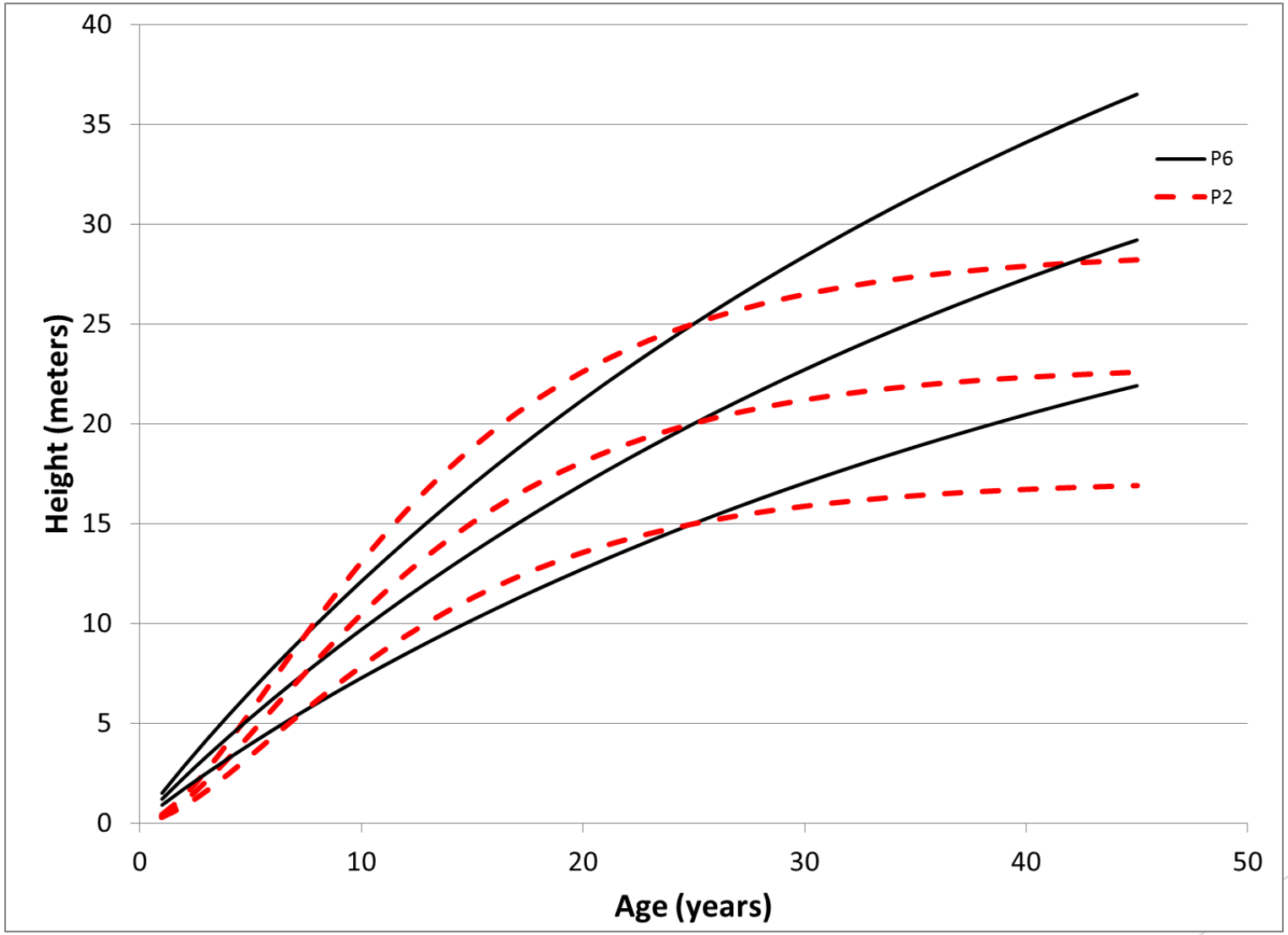
Prediction bias across 5-year age classes: Chapman-Richards



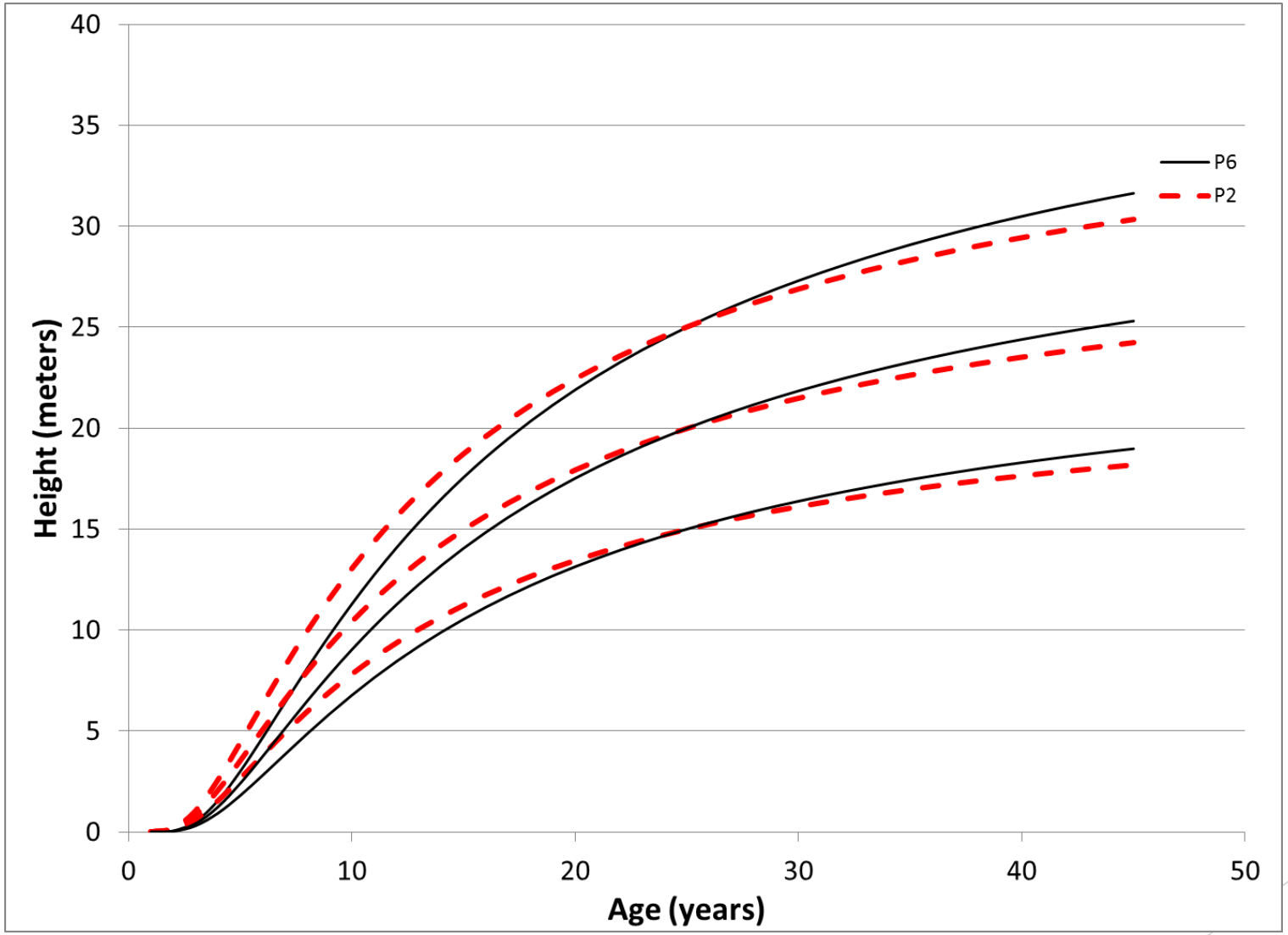
Prediction bias across 5-year age classes: Schumacher



Site Index Curves: Chapman-Richards



Site Index Curves: Schumacher



Summary

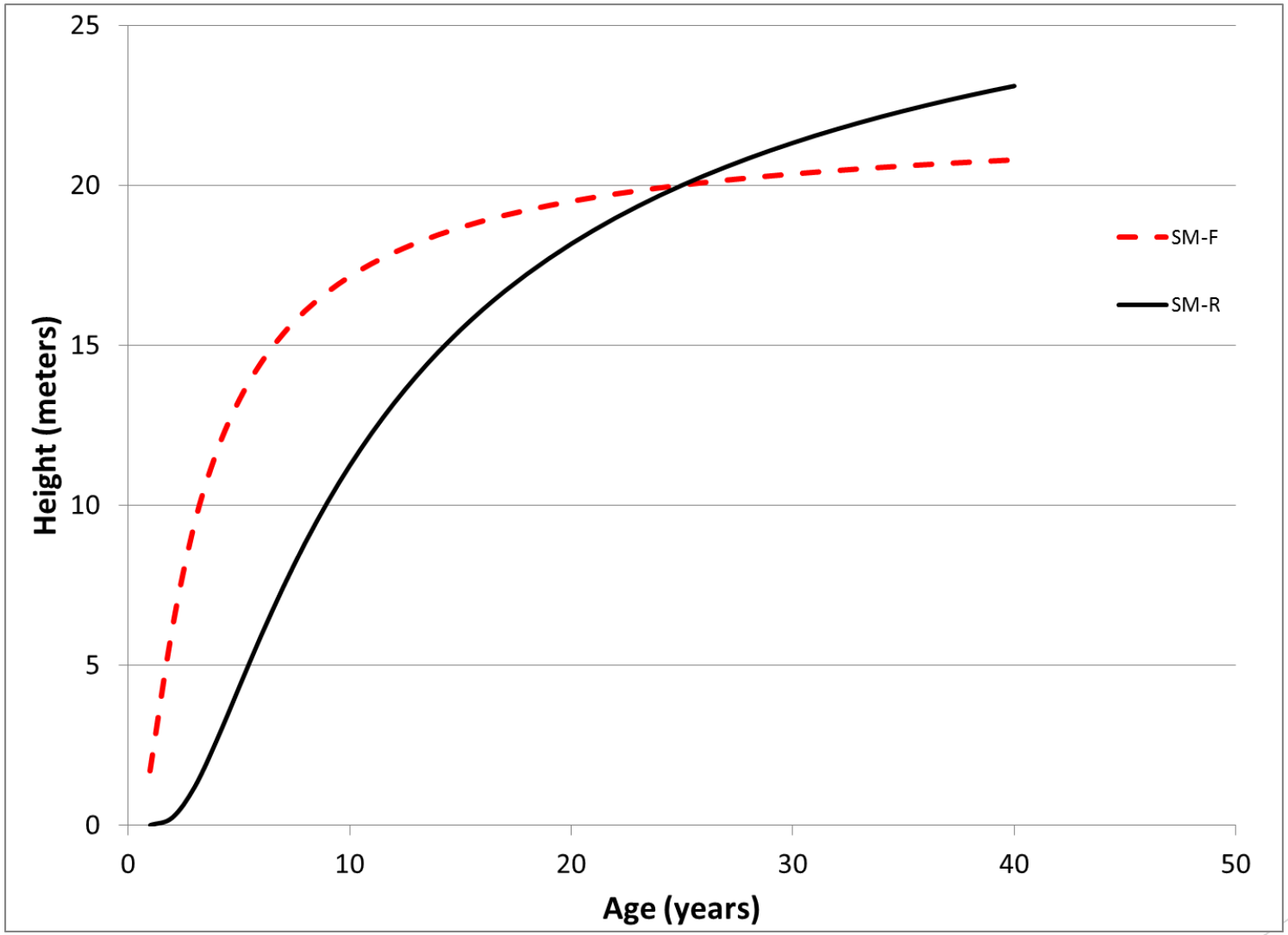
- Large effect in Chapman-Richards model
  - Different dominant stand height growth patterns exhibited
- Little effect in Schumacher model
  - Potentially due to single parameter estimation
- Reasonable to assume dominant stand height development is well defined by the sixth measurement
- Data from a 7^{th} and 8^{th} measurement showed no improvement and site index curves produced were essentially the same as those developed using six measurements

Comparison of models fitted to alternative data sources

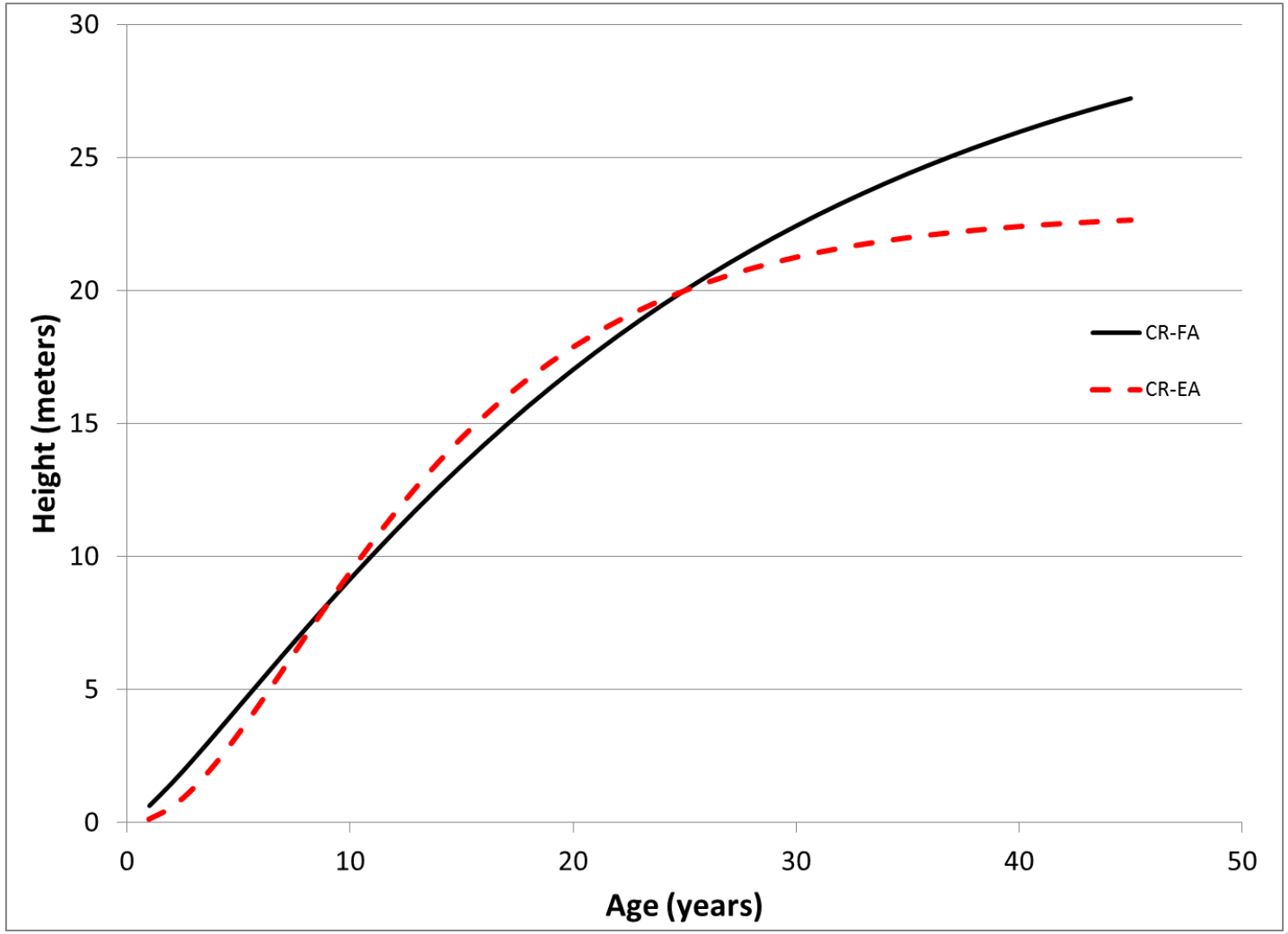
- Dominant height projection models fit to stem analysis and permanent plot data (that included six measurements or less)
- Dominant height prediction models fit to temporary plot data

- Two problems
  - Schumacher fit to stem analysis data
  - Chapman-Richards fit to temporary plot data

Schumacher: Stem Analysis



Chapman-Richards: Temporary Plot



Comparison of models fit to alternative data sources

- Fit dominant height projection models using permanent plot data with six measurements or less
- Fit dominant height projection models using stem analysis data
  - Correct Schumacher model by fitting to data of age eight or greater
- Fit dominant height prediction models using temporary plot data
  - Correct Chapman-Richards model by fixing asymptote at 30 meters

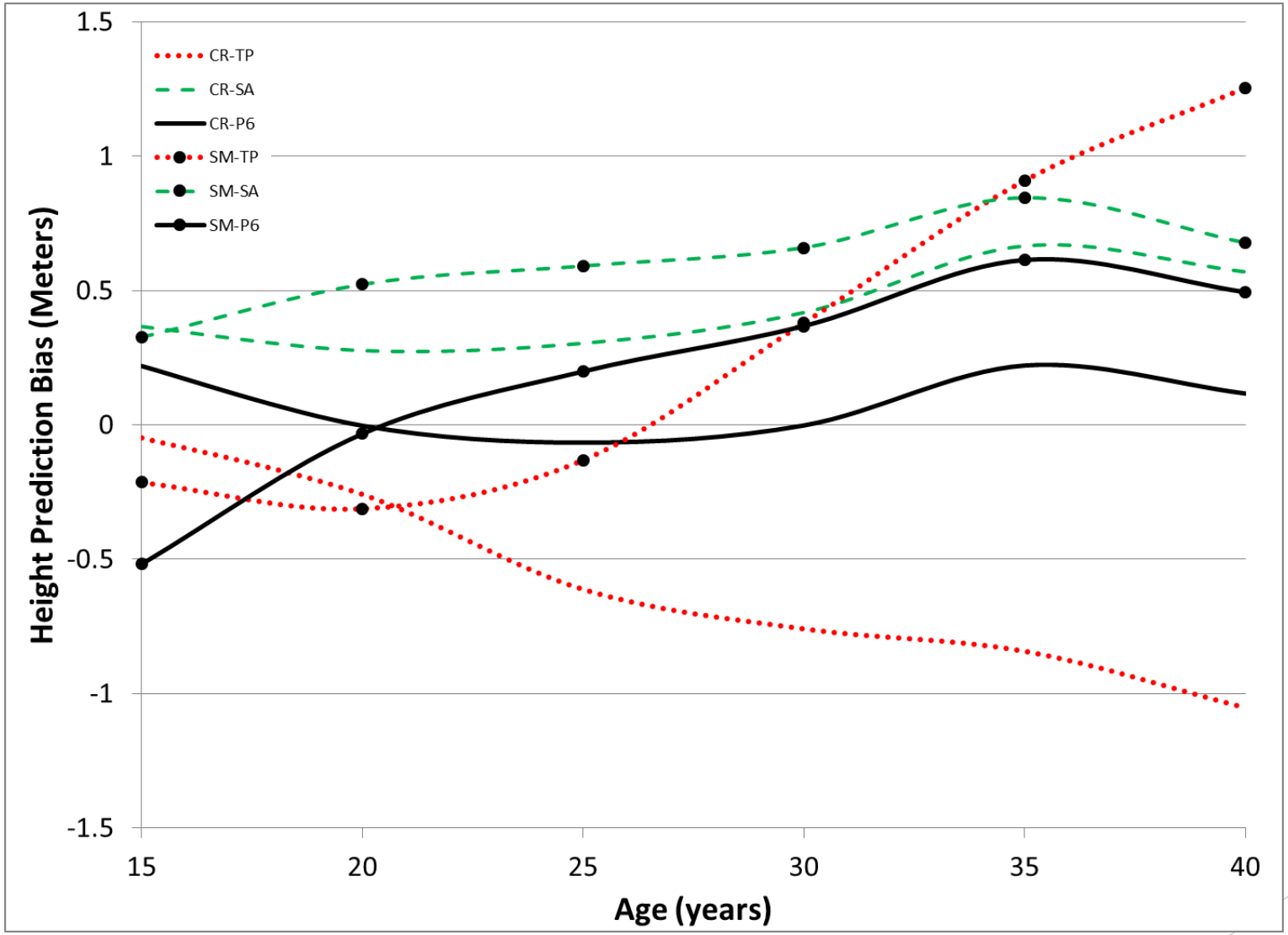
Parameter Estimates

Model	Data Source	β_1	β_2	β_3	SE β_1	SE β_2	SE β_3
Chapman-Richards							
	P6		0.0303	1.0267		0.0037	0.0425
	SA		0.0601	1.1688		0.0034	0.0200
	TP	30	0.0470	1.2794		0.00383	0.1064
Schumacher							
	P6		13.1742			0.1756	
	SA		9.6117			0.1052	
	TP	29.8479	12.7192		1.2878	0.6692	

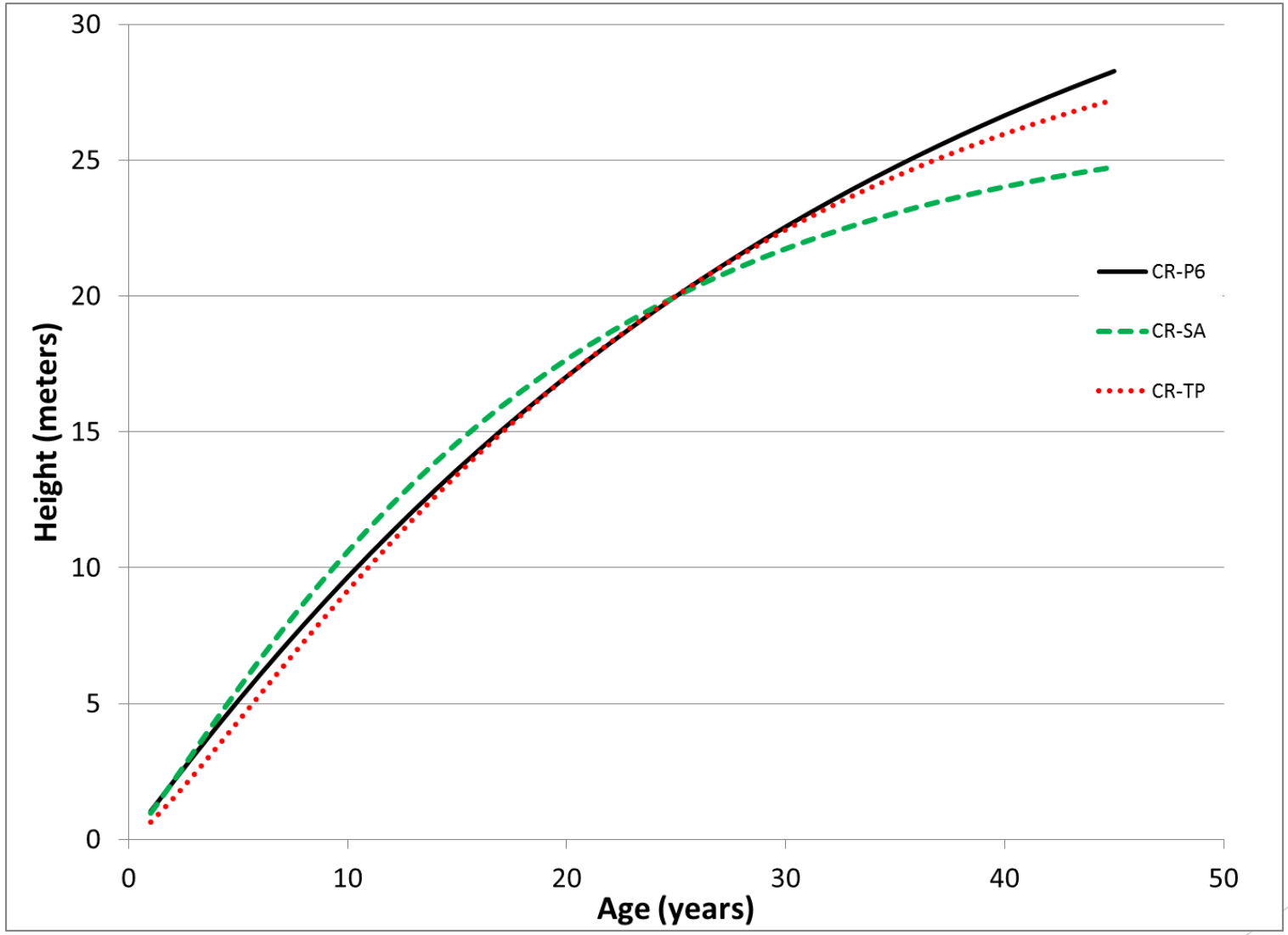
Dominant height prediction bias (observed – predicted) (meters)

Model	Data Source	Abs Mean	Mean	St Dev	Min	Max
Chapman-Richards						
	P6	0.4630	0.0334	0.5858	-2.1196	2.4456
	SA	0.5551	0.3933	0.5921	-1.8914	2.8901
	TP	1.6590	-0.4761	2.1006	-6.3929	6.9416
Schumacher						
	P6	0.5309	0.2045	0.6568	-2.6392	2.8383
	SA	0.6877	0.6092	0.5850	-1.7605	3.0631
	TP	1.6214	0.0124	2.1188	-5.4984	8.2972

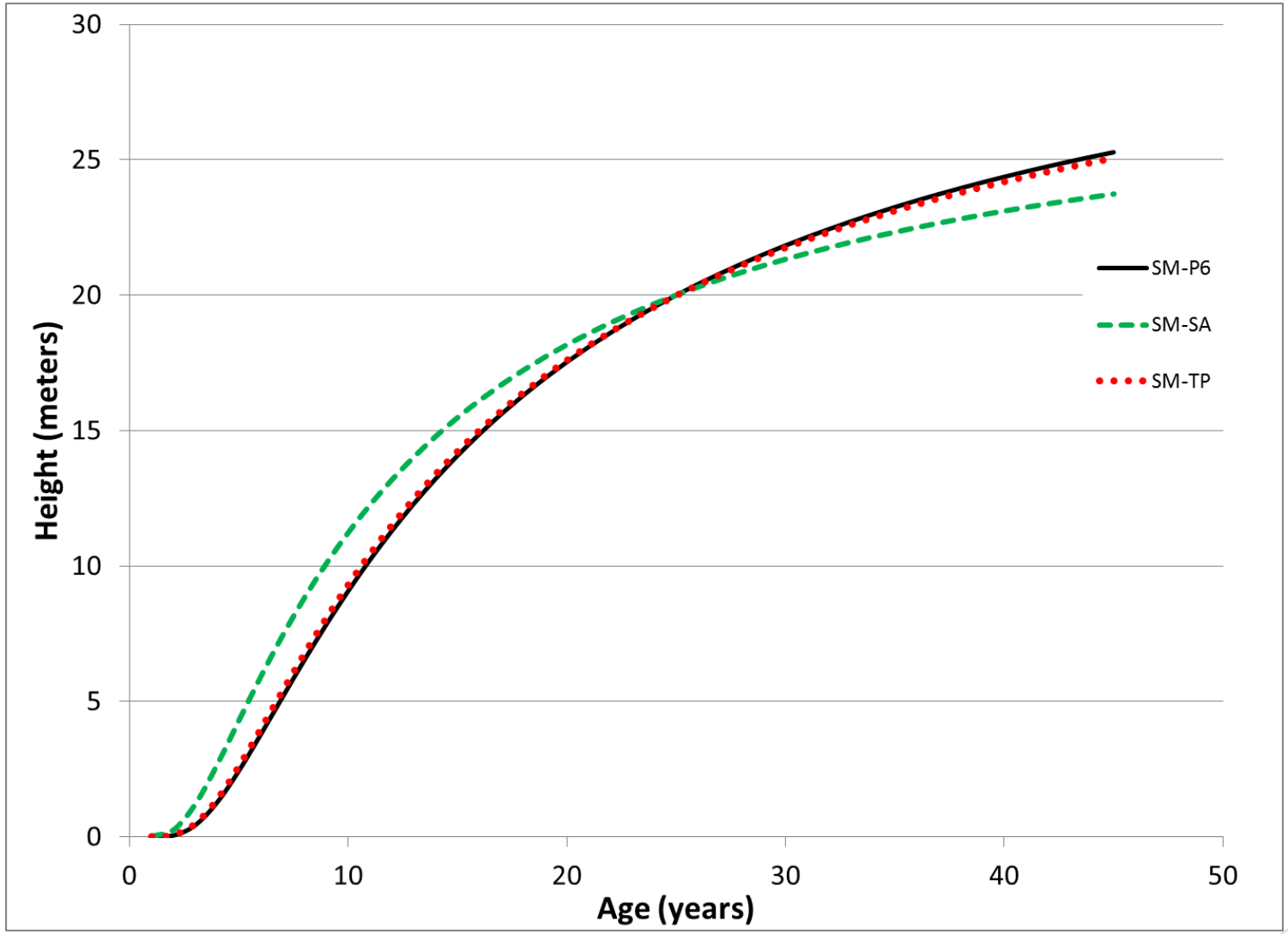
Prediction Bias by 5-year Age Classes



Site Index Curves: Chapman-Richards



Site Index Curves: Schumacher



Conclusions

- This study used data from a common population for fitting two models to three data types
- Models fit to permanent plot data had best accuracy and lowest mean absolute bias
- Models fit to stem analysis data had lower mean absolute bias as compared to those fit to temporary plot data and is the preferred alternative for fitting height-age equations
- For the purpose of constructing site index curves models based on temporary plot data produced curves closer to those developed from permanent plot data

Conclusions

- Site index curves produced by the Chapman-Richards model developed from initial measurement data (temporary plot data) leveled excessively in older ages
  - No correlation between stand age and site index
  - Functional form of Chapman-Richards model
    - Fit to dominant heights of plantations 8 to 25 years resulted in low estimate of the asymptote parameter
    - Cause excessive leveling in ages greater than range of data used for model fitting

Conclusions

- Site index curves produced by the Schumacher model fit to stem analysis data were overly steep before inflection point of height growth and then flattened after
  - Steepness in curves has been contributed too:
    - Poor model form
    - Stem analysis trees not always in dominant canopy
  - Problem in the model form when fitting to data that includes the juvenile stage

Questions