# MODELLING STAND GROWTH AND YIELD RESPONSE TO SILVICULTURAL TREATMENTS

Plantation Management Research Cooperative

Daniel B. Warnell School of Forest Resources

The University of Georgia

PMRC Technical Report 1995-2

L. V. Pienaar and J. W. Rheney

Executive Summary.

Increased productivity resulting from more intensive silvicultural treatments is most readily apparent in increased height growth. This report represents an attempt to model height growth response to silvicultural treatment and evaluates its effect on stand basal area and volume in the context of existing PMRC yield prediction models.

Height growth response to any new or additional silvicultural treatment is evaluated in relation to some assumed norm or standard silvicultural practice. An adjustment term is added to the existing height growth model to represent the cumulative effect of such a treatment on average dominant/codominant height.

Data from the PMRC slash pine site preparation study are used to evaluate the proposed average dominant height growth model, with the chop and burn treatment assumed to be the standard practice. Results presented for the bedding and herbicide treatments indicate that the proposed model fits the observed average height growth trends well, with an increase in average dominant/codominant height of as much as 12 ft at age 14.

Average dominant/codominant height is a predictor variable in the existing PMRC basal area prediction model, in addition to the surviving number of trees per acre and age. It underpredicts the basal area for plots that received the more intensive silvicultural treatments. An additional term in the model, of the same form as in the height growth model, is used to adjust the predicted basal area. The existing PMRC volume prediction model uses basal area as a prediction variable, in addition to average dominant/codominant height, surviving trees per acre and age. When accurate estimates of basal area and height are available, no adjustment of this

model is required to predict per-acre volume for the more intensive silvicultural treatments.

## Modelling Stand Growth and Yield Response
## to Silvicultural Treatments

The PMRC has been partly responsible for the continuing evolution of silvicultural practices in this region. As a result, those of us in the growth and yield modelling business always seem to be a day late and a dollar short. By the time yield prediction models are fully developed and validated, they are obsolete unless they can be adjusted somehow to reflect the responses to different silvicultural practices.

Increased productivity expected from silvicultural treatments may simply be the result of increased survival, but most often increased productivity is most readily apparent in increased height growth. This report is an attempt to model height growth response to silvicultural treatment and to evaluate its effect in the context of existing stand basal area and volume prediction models.

Modelling Dominant Height Growth Response.

Different silvicultural treatments may have different effects on height growth over the life of a stand. Both the magnitude and the pattern of the response may differ. In addition to the absolute magnitude of the response, some treatments may have only a relatively brief positive effect, while others may have a longer lasting effect, depending on the treatment and the site. It will be assumed that the height growth response to any additional or new silvicultural treatment will be evaluated in terms of some norm or standard silvicultural practice. The following average dominant height growth model is proposed:

$$H = a_1(1 - e^{-a_2 Age})^{a_3} + b_1 \, YST e^{-b_2 YST}$$

where H is average dominant height and YST is the number of years since the treatment was applied.

The first term in this model defines the expected dominant height growth curve for the standard silvicultural treatment and for a given site or soil class. The second term represents the cumulative effect of a new or additional treatment on average dominant height over time. Parameters $b_1$ and $b_2$ determine the magnitude and pattern of the response. The maximum cumulative response is $(b_1/b_2)e^{-1}$, and is attained $(1/b_2)$ years after treatment. For a given maximum response [$(b_1/b_2)$ ratio], the $b_2$ parameter determines the pattern of the response. Figures 1 and 2 illustrate response patterns that can be generated with different parameter values when the treatment is applied at the time of stand establishment and at age 12 respectively.

To see how this might work, 14-year response data from the PMRC slash pine site preparation study on spodosols (9 locations) were used to fit this model. The following site preparation methods were used:

| | |
|---|---|
| 1. Chop, Burn. - | A single pass with a drum chopper after harvest of previous plantation, followed by a broadcast burn. |
| 2. Chop, Burn, Bed. - | Treatment 1 plus a double pass bedding operation. |
| 3. Chop, Burn, Herbicide. - | Treatment 1 plus complete control of competing vegetation. |
| 4. Chop, Burn, Bed, Herbicide. - | Treatment 2 plus complete control of competing vegetation. |

**FIGURE1. HEIGHT GROWTH FOLLOWING TREATMENT AT STAND ESTABLISHMENT GENERATED WITH DIFFERENT VALUES OF THE b1 AND b2 PARAMETERS IN EQUATION (1) AND WITH a1=100, a2=0.05, AND a3=1.2**

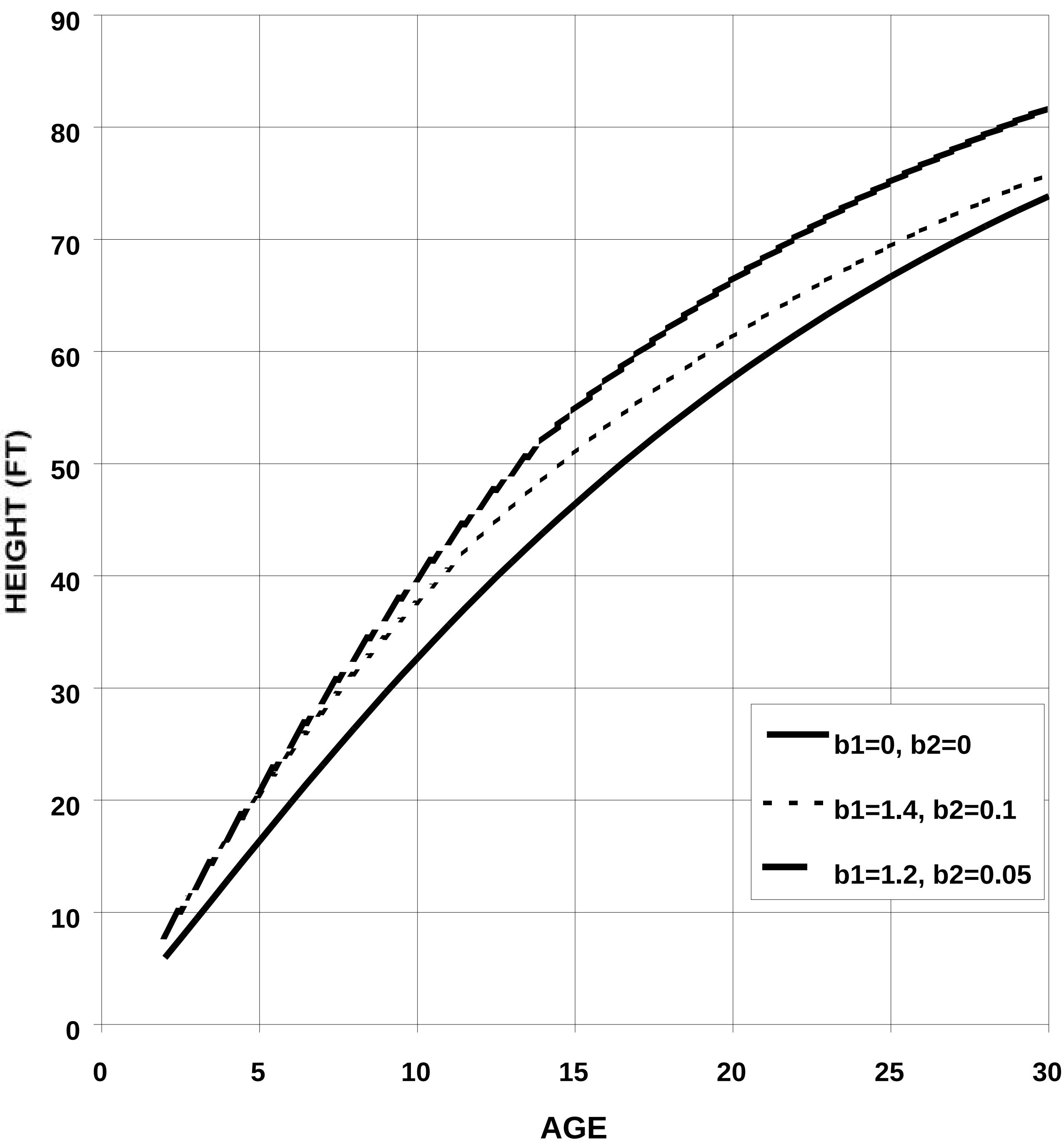
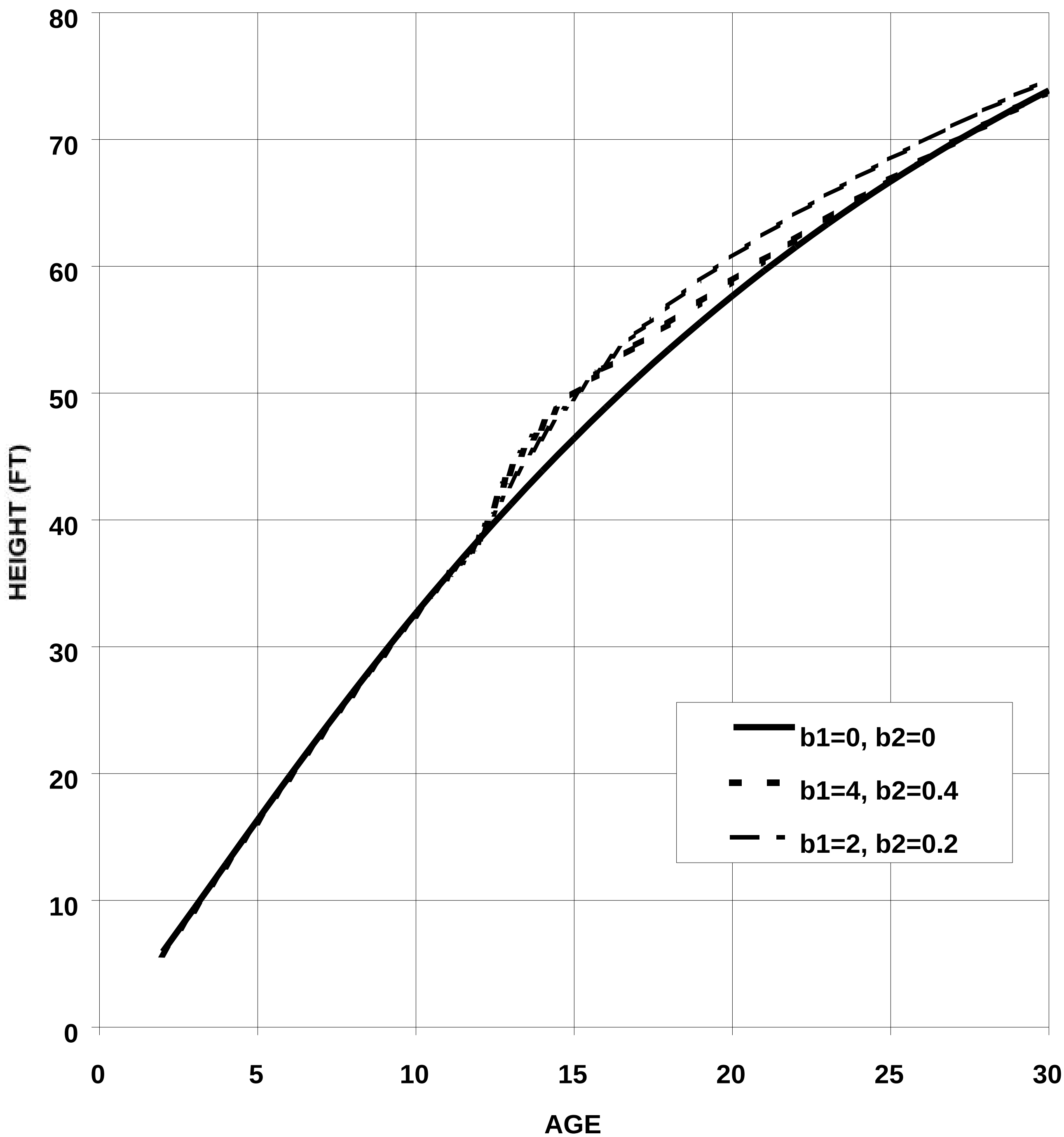


**FIGURE 2. HEIGHT GROWTH FOLLOWING TREATMENT AT AGE 12 GENERATED WITH DIFFERENT VALUES OF THE b1 and b2 PARAMETERS IN EQUATION (1) AND WITH a1=100, a2=0.05, AND a3=1.2**



Treatment 1 was considered the standard treatment and indicator variables were used to represent the effects of bedding and of herbicide treatments on the response parameters $b_1$ and $b_2$ in the model. The following result was obtained:

$$H = 93.6(1 - e^{-.066Age})^{1.806} + (.648Z_1 + 1.867Z_2)YST\ e^{-.077YST}$$

# Obs = 160 $\qquad R^2 = .93 \qquad$ S. e. = 3.3 ft.

where $Z_1$ = 1 if bedded, zero otherwise and $Z_2$ = 1 if competition controlled, zero otherwise.

The $b_2$ parameter did not differ significantly for the two treatments, and there was no significant interaction between the treatments in their effect on the $b_1$ parameter. Observed treatment means and fitted average dominant height growth curves are shown in Figure 3.

Another PMRC study, the slash pine mid rotation competing vegetation study, provided 12-year response data for a treatment applied later in the life of a stand. In this study all competing vegetation was eliminated at about midrotation age in one of two paired plots. Age at the time of treatment was 11 years. With the average dominant height of the untreated plots as the norm, the following results were obtained for the 7 locations on poorly drained spodisols:

$$H = 97.2(1 - e^{-.052Age})^{1.384} + .627YST\ e^{-.030YST}$$

# Obs = 14 $\qquad R^2 = .99 \qquad$ s.e. = 0.7 ft.

Observed average dominant heights and the fitted curves are shown in Figure 4.

**FIGURE 3. OBSERVED AVERAGE DOMINANT HEIGHT AND PREDICTED HEIGHT GROWTH CURVES FOR DIFFERENT TREATMENTS**

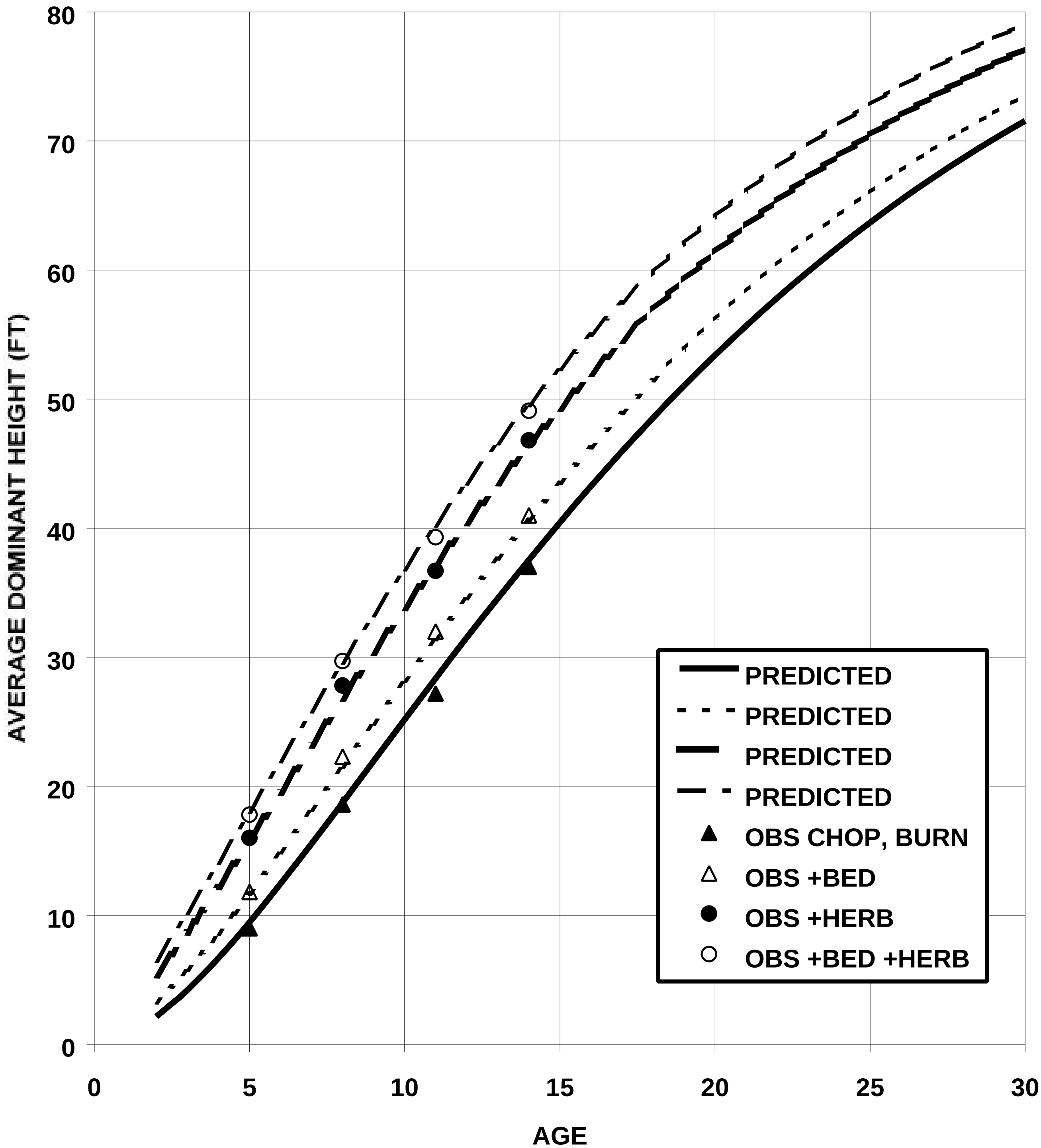
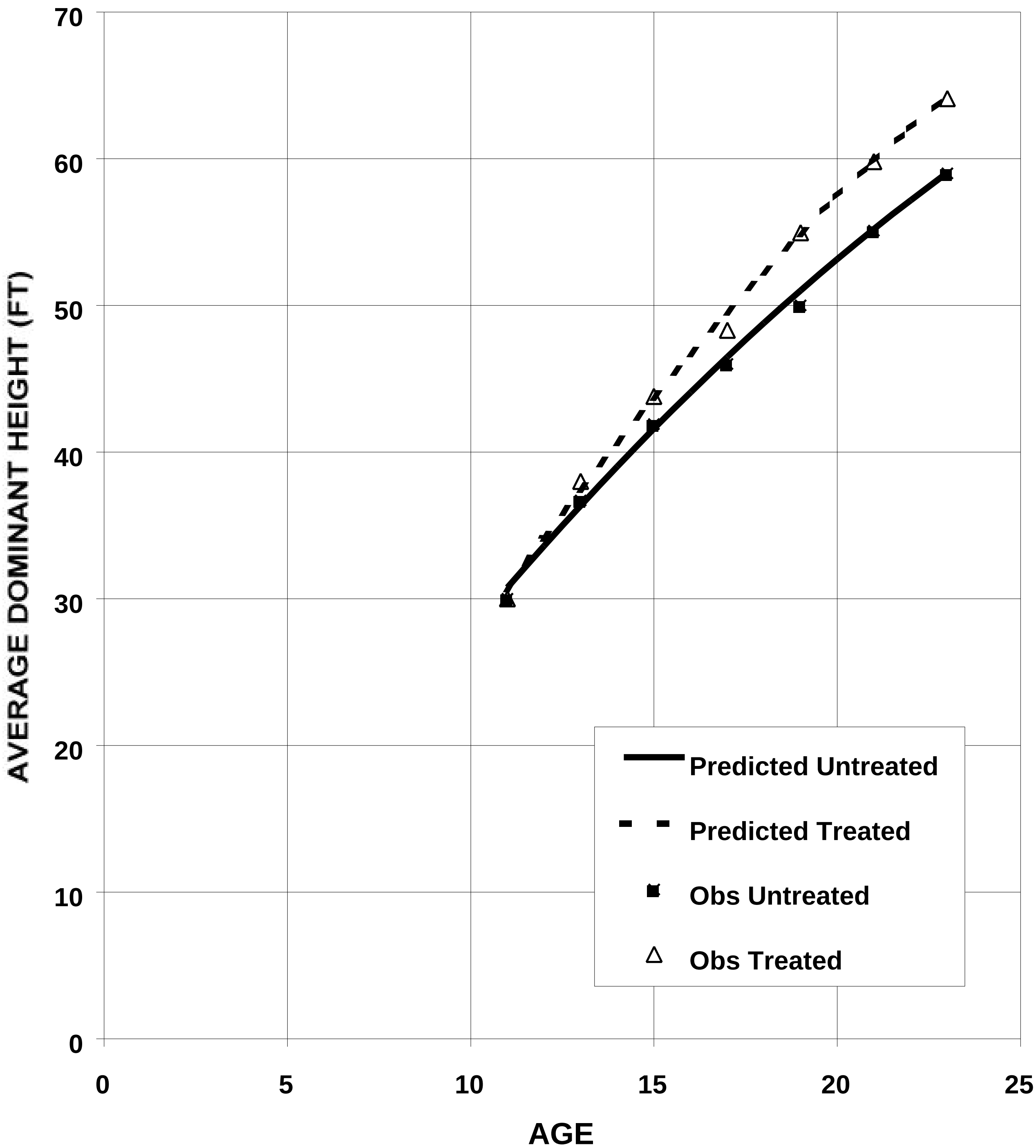


**FIGURE 4. OBSERVED AND PREDICTED AVERAGE DOMINANT HEIGHT AFTER HERBICIDE TREATMENT AT AGE 11**



Stand Basal Area Prediction

We have an existing basal area prediction model for unthinned slash pine plantations in which average dominant height is one of the predictor variables. It has the form:

$$B = e^{a_1 + a_2/Age} \; H^{b_1 + b_2/Age} \; N^{c_1 + c_2/Age}$$

where B is per-acre basal area (ft), H is average dominant height (ft) and N is number of surviving trees per acre.

The question is whether the same parameter estimates will suffice regardless of silvicultural treatment, given an accurate prediction of average dominant height. Since the treatment may not only affect height growth but also stem form and diameter distribution, additional terms can be added to this model to represent the cumulative effects of the treatments, as in the height growth model. Data from the PMRC site preparation study were used to fit such a model:

$$B = e^{-4.399 \; -13.482/Age} \; H^{1.290 + 5.083/Age} \; N^{.576} + (2.424 Z_2 - .511 \; Z_1 \; Z_2) \; YST e^{-081 \; YST}$$

\# Obs= 160 $R^2$ = .99 s.e. = 3.8 $ft^2$

As before, Chop and Burn was considered the standard treatment. When only the bedding treatment is added no additional adjustment to the basal area prediction equation is required. When the herbicide treatment is added, however, with or without bedding, the adjustments to the predicted basal areas significantly reduce the residual sum of squares for this model.

Figure 5 shows the observed and predicted average basal areas for the different treatments. Even though the full pattern of the treatment responses are yet to be observed, the model fits the data well through age 14.

Stand Volume Prediction.

We have also developed a stand volume prediction model for slash pine plantations in which both average dominant height and basal area are predictor variables

$$V = e^{a_1 + a_2/Age} H^{b_1 + b_2/Age} N^{c_1 + c_2/Age} B^{d_1 + d_2/Age}$$

where V is per-acre stem volume outside bark. As in the case of stand basal area, additional response terms were added to this model to represent treatment effects, and the model was fitted to the same PMRC data. In this case the adjustment term did not improve the volume predictions significantly. The following volume prediction equation was obtained:

$$V = e^{-1.506/Age} H^{.860} N^{.030 + .251/Age} B^{1.018}$$

# Obs = 160 $R^2 = .99$ s.e. = 10 $ft^3$

The conclusion is that when accurate estimates of average dominant height, per-acre basal area, and surviving trees per acre are available, no adjustment of this model is required to account for the different silvicultural treatments. Observed and predicted average per-acre volumes are shown in Figure 6.

FIGURE 5. OBSERVED AND PREDICTED BASAL AREA FOR DIFFERENT TREATMENTS

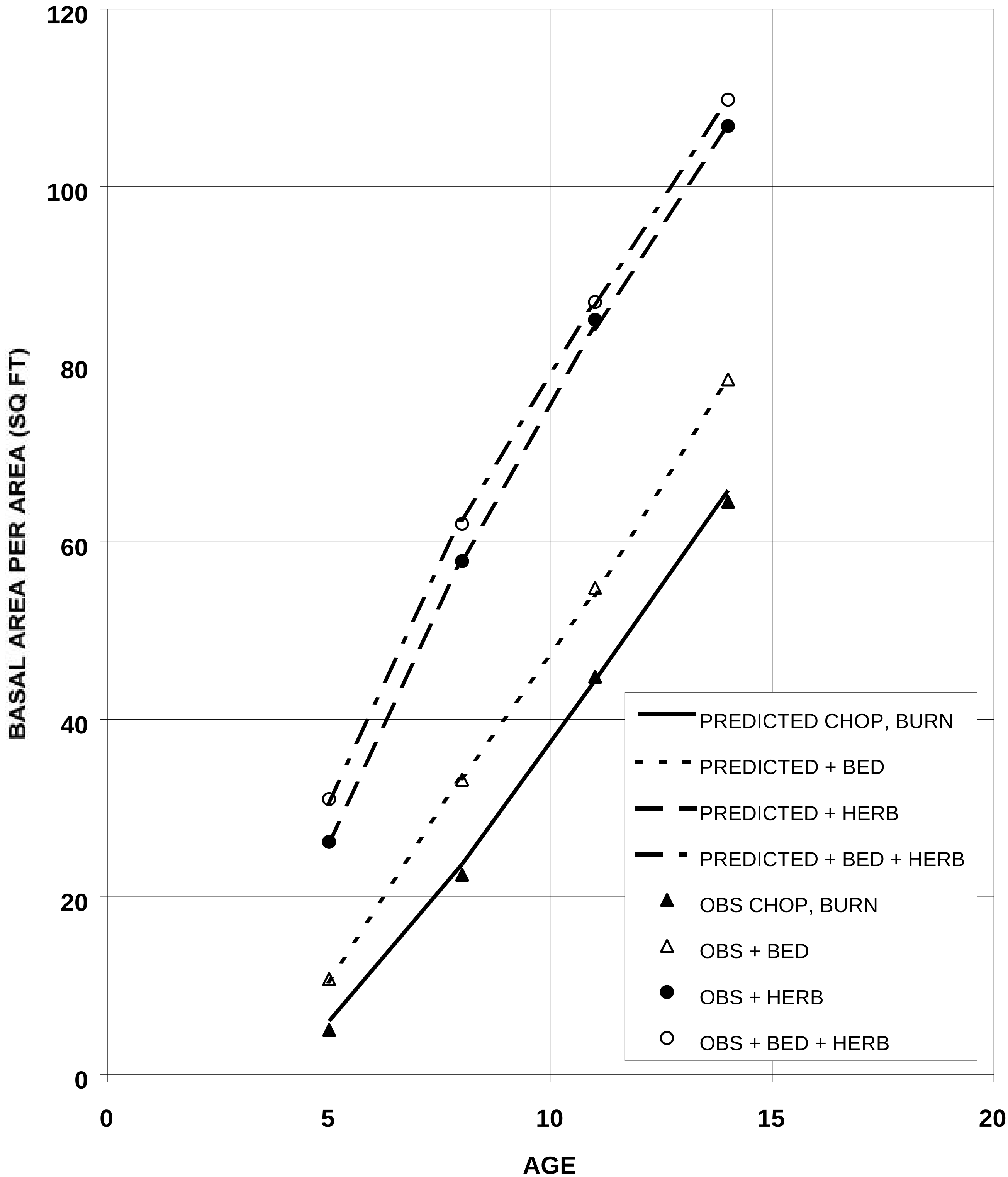


FIGURE 6. OBSERVED AND PREDICTED VOLUME GROWTH FOR DIFFERENT TREATMENTS