Northern California Forest Yield Cooperative
Department of Environmental Science, Policy, and Management
University of California, Berkeley, CA 94720

Research Note #40 February 18, 1994
(revised August 30, 1994)

A comparison of CACTOS short-term growth projections with observed growth

by

Lee C. Wensel and Eric C Turnblom

The current coefficients in CACTOS were developed as a sequential process over both stem analysis and remeasurement data from (initially) 710 permanent plots measured by the industry members of the Northern California Forest Yield Cooperative. The stem analysis data were used to develop initial estimates of the growth coefficients for both tree DBH and height as well as to estimate the crown profiles. The first remeasurement of the growth plots were used to revise these DBH and height growth coefficients for what are the current coefficients in CACTOS. (The crown models still are based upon the original stem analysis data.) Mortality estimates are based upon this single 5-year growth period.

We now have a second remeasurement upon which we have been evaluating the CACTOS coefficients. Initial comparisons of predicted with observed changes in the plots have been summarized. While there is some variation by species, basal area growth was overestimated while mortality was underestimated for all growth periods.

GROWTH PERIODS

The dates of the first, second, and third measurement vary and these measurements are defined by the range of dates indicated in Table 1. A common 5-year sequence of remeasurement would have measurements in 1979, 1984, and 1989. Alternatively, the measurements could have been in 1980, 1984, 1991 with 4 years in the first period and 7 years in the second period. Such variation in the remeasurements were beyond our control.

TABLE 1. DEFINING MEASUREMENT SEQUENCES AND SAMPLE SIZES.

measurement	years measured[1]	growth period	meas. interval	plots (no.)
1	1979 - 1983			
		first	1 to 2	609
2	1984 - 1987			
		second	2 to 3	562
3	1988 - 1991			
		both	1 to 3	623
all	1979 - 1991			

[1] Nominal growth period was five years with measurement of individual plots within the ranges of years shown. For example, a typical sequence might have measurements in 1979, 1984, and 1990.

BASAL AREA GROWTH RATES

The following comparisons are based upon the 609 plots that were available as of December 1993. The "compare" function in CACTOS version 5.0 was used to examine the observed and predicted changes on the plots for which data were available. Overall, there were 623 plots on which a first and third measurement were available. Also, there were 562 plots on which second and third measurements were available.

The uncalibrated comparisons of the survivor growth based upon the first, second, and both measurement intervals are shown in Table 2. Table 2 reveals that basal area growth rates are significantly over predicted for many, but not all, of the species. However, statistically significant over predictions may not be troublesome if they are small enough. For example, white fir in the first period shows as statistically significant over prediction of 4%. However, the over predictions for some of the other species are a problem whether they are statistically significant or not. The large differences for some species, such as tanoak, are not statistically significant because of the high variance and few plots on which they occur. These figures also show considerable difference in actual growth rates between the first and second periods. Caution must be exercised in interpreting these differences because of the changing numbers of plots and changing individual trees within those plots that are used in each period.

TABLE 2. FIVE-YEAR BASAL AREA SURVIVOR GROWTH (SQUARE FEET PER ACRE)

	observed basal area					predicted growth•			no. of plots		
	stocking		growth								
Species	initial per. 1	initial per. 2	period 1†	period 2†	both‡	period 1†	period 2†	both‡	period 1	period 2	both
Ponderosa Pine	66.1	64.2	6.3	4.9	10.0	7.0*	6.3*	11.9*	413	388	433
Sugar Pine	27.3	28.2	3.5	2.9	5.7	3.3	2.9	5.7	342	315	347
Cedar misc.	36.5	37.1	4.1	3.7	7.1	3.1*	2.9	5.9*	399	380	427
Douglas-fir	45.1	48.8	7.1	7.4	13.4	7.0	7.8	13.8	342	314	343
White Fir	67.6	67.6	9.9	9.0	18.0	10.3*	9.4	18.8	460	433	487
Red Fir	63.3	56.2	7.5	7.6	14.2	8.0	8.8*	16.4	54	40	50
Lodgepole Pine	34.9	21.8	2.2	0.5	1.2	3.7	1.1	2.7	7	8	9
White Pine	11.0	9.3	0.6	0.3	1.3	1.2	0.7	2.4	3	4	5
Jeffrey Pine	61.5	59.5	4.7	3.6	5.7	5.3	4.5	8.0*	8	7	11
Tanoak	27.4	31.8	7.3	4.6	8.5	11.7	9.1	18.1	11	7	7
Black Oak	16.4	16.6	0.7	0.7	1.6	2.2*	2.5*	5.5*	146	149	180
Hdwd misc.	25.4	23.7	3.1	1.5	3.0	6.9*	6.6*	11.3*	74	61	70
Chinquapin	14.7	16.1	1.3	1.5	2.8	1.6	1.5	2.7	1	1	1
conifer misc.	3.6	2.9	0.4	0.4	0.8	0.6	0.6	1.1	11	10	10
total¤	175.0	176.9	21.8	19.6	38.6	22.8*	21.8*	42.4*	609	562	623

• All predictions were with CACTOS coefficient file 411.

* Statistically significant differences at the 95% level of significance. Due to the few plots on which some species were present, and the higher variance of responses, some rather large differences do not appear to be statistically significant.

† Basal area per acre scaled as growth for the nominal 5-year period.

‡ Basal area per acre scaled as growth for the nominal 10-year period.

¤ Because the same plots are not used for each species, the columns are not additive.

Keeping the trees used in the comparison constant over time, as in Table 3, allows us to address the question of reduced growth during the second period in more detail. This table compares growth only on trees that survived both measurement periods, here-to-fore referred to as "super" survivors. This clearly shows a substantial reduction in growth of the second period. In fact, the reduction in observed growth is greater than shown by the differences in the observed growth columns for the two periods. For example, consider ponderosa pine. The predicted growth was 0.8 sq. ft. more for the same trees in the second period than the first (due to changing tree size and competition). Thus if the same climatic conditions had prevailed in the second period as the first we should have observed 7.0 + 0.8 = 7.8 sq. ft. of growth. This is considerably more than the 5.9 sq. ft. actual observed. A similar adjustment can be applied to the other species in the second measurement. Using this scenario, while sugar pine appears to have grown at approximately the same rate during the second period, the difference in predicted growth rates suggests a larger reduction from what the growth would have been had the trees had the same climate in the second period as the first.

We've made arrangements to get estimates of changes in rainfall over the prediction periods to see if these changes in growth can be correlated with weather patterns. This may help us decide which of the growth periods should be used for modelling. We may even be able to use both periods for growth modelling if suitable "adjustments" to the norm can be developed. We don't know now what the relationship is between the rainfall recorded for the years in question and the long term "norm". As shown by the differences in growth rates for the periods, this certainly must be determined so that CACTOS can predict "normal" growth rates.

TABLE 3. FIVE-YEAR BASAL AREA "SUPER" SURVIVOR GROWTH (SQ. FT. / ACRE)

	observed basal area	growth		predicted growth		plots
Species	initial	period 1	period 2	period 1	period 2	(no.)
Ponderosa Pine	58.2	7.0	5.9	7.1	7.9	365
Sugar Pine	25.9	4.0	3.8	3.6	4.0	272
Cedar misc.	37.0	4.8	4.1	3.7	3.8	349
Douglas-fir	38.4	7.3	7.0	7.0	8.7	294
White Fir	52.9	9.8	8.9	9.6	10.5	415
Red Fir	40.5	6.9	6.5	6.8	7.3	38
Lodgepole Pine	20.0	1.6	1.2	2.6	2.8	4
White Pine	13.2	0.9	0.9	2.0	2.1	1
Jeffrey Pine	29.7	3.4	3.0	2.5	2.4	8
conifer misc.	1.9	0.3	0.4	0.5	0.6	10
Chinquapin	9.3	0.8	0.9	1.1	1.1	2
Black Oak	17.2	0.9	0.8	2.0	2.1	128
Tanoak	19.3	5.6	5.9	4.4	6.1	6
Hdwd misc.	27.0	2.5	2.1	3.8	4.2	46

MORTALITY RATES

Table 4 gives the observed and predicted mortality rates for all plots. The comparison of observed and predicted mortality shows "substantially" higher observed mortality than predicted for all species except Douglas-fir and Jeffrey pine. Also, it shows higher mortality for the second period than for the first.

INGROWTH RATES

Ingrowth which occurred during the two measurement intervals appears in Table 5. In contrast to the mortality and growth rates, for ingrowth there appears to be little difference between periods. Further, it appears that we should be able to produce an optional rate of ingrowth to apply as a function of density and vegetation class. Improved mortality and ingrowth estimates are under consideration.

RAINFALL LEVELS

Rainfall levels for the rainfall years (October through September) are shown in the Figure 1[2]. It appears clear from this figure that differing rainfall levels in each growth period may well be the principal cause of varying growth rates on the sample plots. If we consider a typical 1979, 1984, 1990 sequence, for example, we see a clear difference in the rainfall between the periods. Adding the previous year to each period we see that 5 of the 7 water years in the period 1979-1984 are above average while in the next period 5 of the 7 water years are below average with 4 consecutive years below the average. This is expected to affect both the growth rates of the trees and the mortality rates. CACTOS growth and mortality models are now being revised to include this information and to produce model estimates for the long-run average rainfall level.

CALIBRATION AND MODEL CHANGES

What do these comparisons mean for the CACTOS model? A detailed analysis has shown that the diameter and height growth over or under predictions are not significantly related to such variables as live crown ratio, CC66, stand density index, basal area, or numbers of trees. This suggests that a proportional calibration should be sufficient to adjust for any periodic effect of weather patterns. These adjustments can be made by each user after an analysis of observed and predicted growth on a "sufficient" number of plots.

This should adjust CACTOS for "short term" projections. For long term projections, more common now with current forest practice rules, a different strategy will have to be employed. First, the rainfall analysis that is now underway (see above) can be used to make adjustments from the currently observed growth to a longer-term "norm".

[2] Rainfall data were obtained from Mr. James Goodridge, California Department of Water Resources (retired).

Second, a new analysis will be made of mortality. The "west-side Sierra" version of Forest Vegetation Simulator (formerly PROGNOSIS), referred to as WESSIN, produces much higher mortality rates and may be of use in changing the form and level of the CACTOS mortality predictions. A brief illustration of CACTOS and WESSIN projections, both with and without mortality effects, for a singe plot is shown in Figures 2 and 3. Figure 2 shows that CACTOS and WESSIN produce similar relationships between stand average DBH when there is no mortality. However, when mortality is entered into both models the CACTOS projected average DBH is only slightly lower while the reduction in average DBH for the WESSIN model is significant, suggesting that the CACTOS mortality, while less, is also coming from larger trees. Figure 3, showing the basal area per acre for the 100-year projection, shows much higher stocking levels both with and without mortality for CACTOS as compared to WESSIN. Clearly a more reasonable mortality function is needed for CACTOS[3].

Third, the revisions to the CACTOS growth models will have to control both the mortality and growth rates as a function of stand density to keep long term estimates in line with what is reasonable. For this, we hope to acquire additional data on the condition, growth and mortality rates in plots of "higher" densities than the current Co-op plots.

[3] Keep in mind that the projections in Figures 1 and 2 are given only for illustration of what happens when the user of the CACTOS and WESSIN allows the two models to grow a single plot with no intervention of ingrowth or additional mortality.

TABLE 4. BASAL AREA MORTALITY (SQUARE FEET PER ACRE)

	observed basal area			predicted basal area		
Species	period 1	period 2	both	period 1	period 2	both
Ponderosa Pine	1.7	2.1	3.6	0.9	0.8	1.4
Sugar Pine	0.6	1.3	1.8	0.3	0.3	0.5
Cedar misc.	1.1	1.1	1.9	0.6	0.6	1.1
Douglas-fir	0.4	0.3	0.6	0.4	0.5	0.7
White Fir	2.0	4.2	5.8	1.4	1.4	2.5
Red Fir	1.3	2.2	4.2	1.2	1.2	2.0
Lodgepole Pine	3.9	1.3	3.7	0.8	0.3	0.8
White Pine	0.0	1.5	1.2	0.1	0.1	0.2
Jeffrey Pine	0.0	1.1	0.7	0.7	0.8	1.0
Tan Oak	0.3	1.3	1.1	0.4	0.3	0.4
Black Oak	1.4	0.8	2.2	0.1	0.1	0.3
Chinquapin	1.7	0.8	0.0	0.2	0.2	0.1
Hdwd misc.	0.0	0.0	2.5	0.1	0.1	0.4
conifer misc.	0.8	0.6	1.5	0.1	0.1	0.2
total	4.7	7.0	11.0	2.6	2.5	4.7

TABLE 5. BASAL AREA INGROWTH (SQ. FT. / ACRE)

	observed basal area	
Species	period 1	period 2
Ponderosa Pine	0.6	0.7
Sugar Pine	0.3	0.2
Cedar misc.	1.0	0.8
Douglas-fir	0.8	1.1
White Fir	1.2	1.6
Red Fir	0.9	0.6
Lodgepole Pine	0.0	0.3
White Pine	0.6	0.2
Jeffrey Pine	0.0	0.9
Tan Oak	2.0	5.2
Black Oak	1.0	0.2
Chinquapin	0.0	0.0
Hdwd misc.	0.2	0.9
conifer misc.	0.0	0.0
total	2.9	3.3

Figure 1. Average rainfall by year for 70 northern California rainfall stations above 1000 feet elevation.

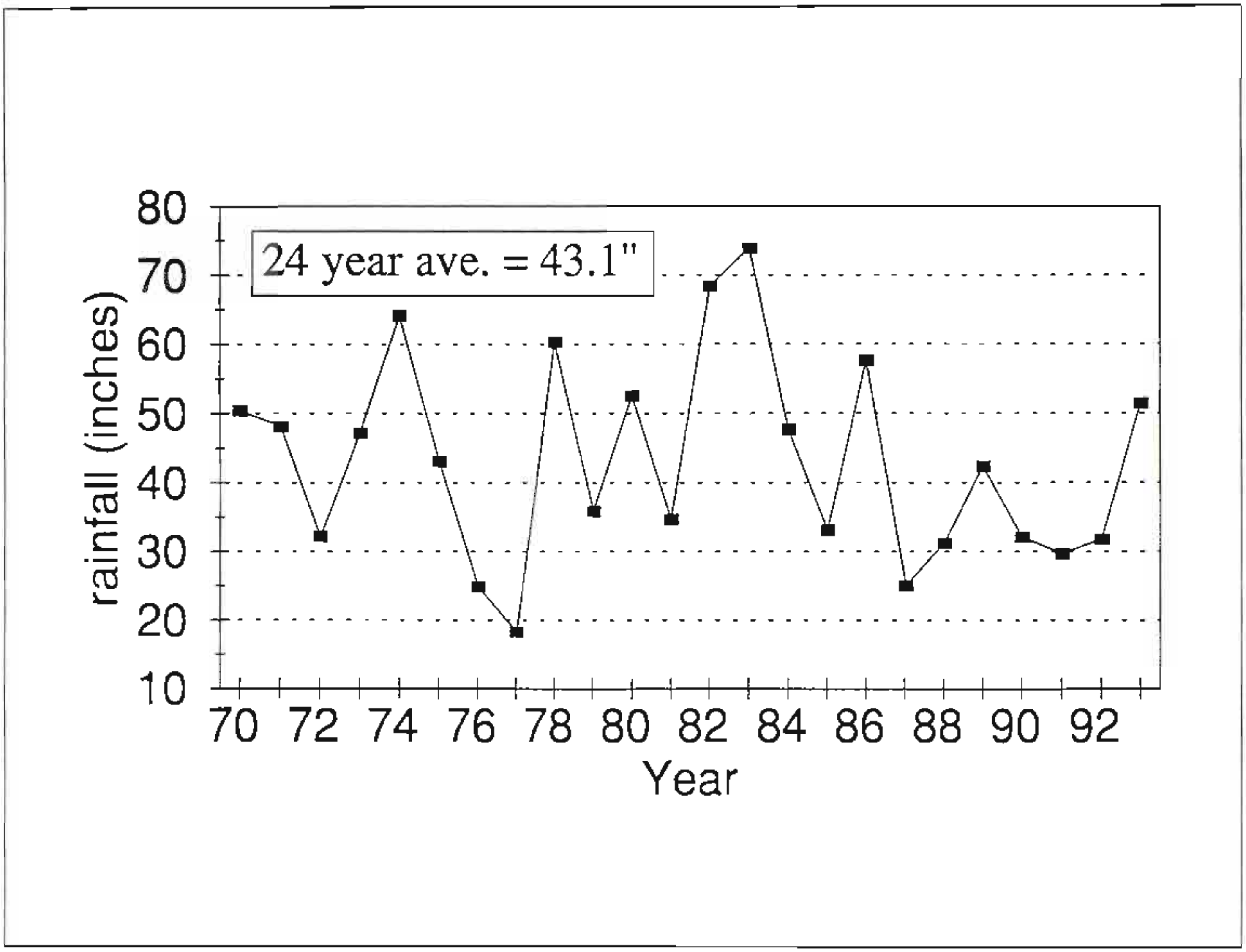

Figure 2. Projected average DBH by year for CACTOS and WESSIN, both with and without mortality.

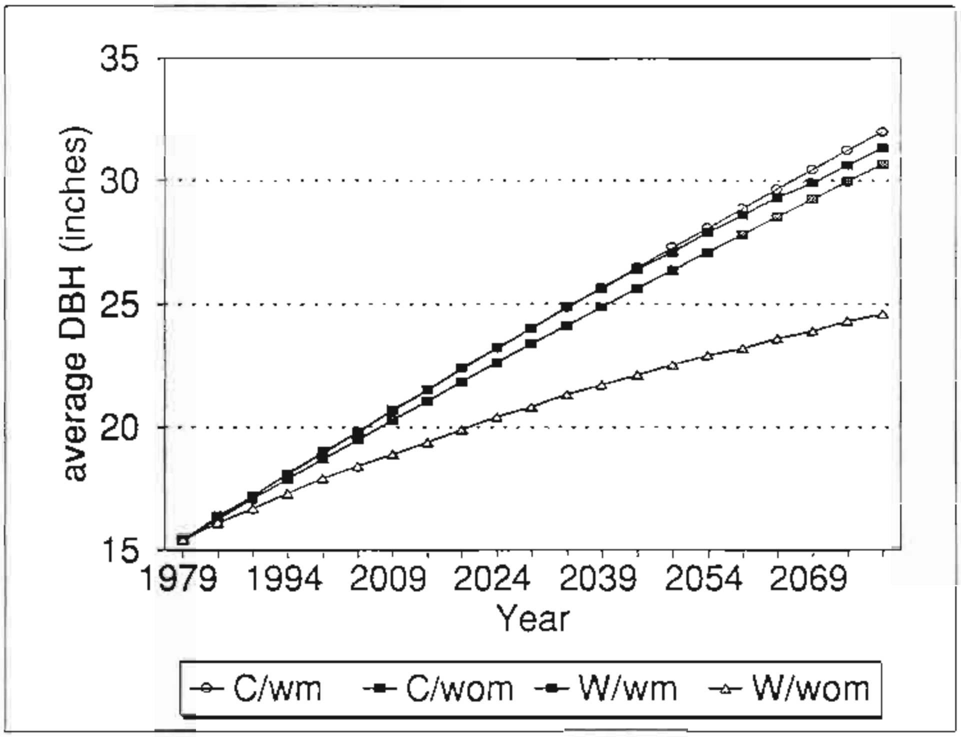

Figure 3. Projected basal area by year for CACTOS and WESSIN, both with and without mortality.