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A REGRESSSION-ADJUSTED APPROACH CAN ESTIMATE COMPETING BIOMASS[1/]

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Abstract .--A method is presented for estimating above-ground herbaceous and woody biomass on competition research plots. On a set of destructively-sampled plots, an ocular estimate of biomass by vegetative component is first made, after which vegetation is clipped, dried, and weighed. Linear regressions are then calculated for each component between estimated and actual weights and are used to adjust ocular estimates of biomass on permanent or temporary plots. In trials, R^2's ranged from 0.57 to 1.00. Training hints and calculation procedures are outlined.

INTRODUCTION

How is competition between a southern pine seedling and surrounding woody or herbaceous vegetation measured? This is a relatively new question. Forest Research has not yet explored fully relations between competition quantifiers and growth responses or other physiological state variables. To be effective, a competition index must indicate the degree of competition for sunlight, growing space, soil moisture or nutrients. This paper examines a regression approach devised to facilitate quantifying above-ground woody and herbaceous biomass in competition research. This method can be used without destructive sampling to estimate bicmass on permanent small-plots, where pines are being established.

Both woody and herbaceous competitors reduce growth of southern pines. Stewart (1981) sumnarized competition control studies for forestry in the United States and has calculated an average increase of 65 percent in conifer volume following hardwood and shrub control. However, most past studies have not related the observed growth responses to measured changes in competing vegetation. Thus, very few relationships between levels of woody competitors and growth of crop trees are documented. Although demonstrated for other forest types, herbaceous competition has only recently been shown to decrease growth in newly-established loblolly pine (*Pinus taeda* L.) plantations (Nelson *et al* 1981; Knowe *et al* 1982; Haywood and Melder 1982). Knowe *et al* (1982) reported a 9-fold increase in 2-year-old tree volume with complete vegetation control. Nelson *et al* (1981) stated that a definable relationship exists between pine height growth and herbaceous biomass.. Carter *et al* (1982) found that, of the quantifiers tested, oven-dry weight of competing biomass around !&year-old loblolly pines had the yrestest linear correlation (r = 0.70) with plant moisture stress during drought periods.

Competition indices successfully used in other regions include plant cover (Oliver 19801, weed tree basal area (Benzie 19771, and shrub crown volume (Bentley *et al* 1971). Unfortunately the indices chosen to date seem to be useful only for specific types of vegetation. A unifying measure is needed for all plant growth forms to permit development of more general response relationships. I suggest that biomass is one quantifying element that may have both general, as well as, local applications. Biomass estimates are currently being employed to assess herbaceous competition on a small scale in the South (Neil *et al* 1982).

The factors limiting widespread use or testing of biomass as a competition index appear to relate to the clip-and-weiyh method. The foremost problems are the large man-power resource required in clipping numerous plots and

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the need for destructive sampling when permanent plots are required. Thus, a method is required that minimizes plot clipping and provides biomass estimates on undisturbed plots. Development of this approach drew upon procedures for quantifying forage biomass presented by Pechanec and Pickford (19371 and Wilm et al (1944). Procedure modifications specified by Blair (1958) were evaluated and will be discussed. Essentially, biomass is visually estimated on a set of plots and then measured by clipping and weighing. A linear regression is then calculated between estimated and actual weights and is used to adjust ocular estimates made on permanent plots. This approach was developed in attempts to gain a standing-crop estimate of competition on a Piedmont cutting-unit, half of which had been sheared-windrowed and half single-roller chopped (Miller 1980).

THE BIOMASS ESTIMATION METHOD

First-Stage Sampling

The double sampling method was developed and tested on a 124 ha management unit of the Union Camp Corporation on the rolling topography typical of the extreme southern Piedmont. The operational unit, divided in half, was prepared with two different site preparation methods prior to planting with loblolly pine seedlings. Reference points were established every 20 m along baselines located along ridge tops within each treatment. Five points in each area were then randomly selected for locating sampling lines. Each year 20 temporary plots (2 x 2 m) were randomly located along sampling lines, 10 per treatment area. On these plots the biomass was both estimated and clipped. Forty permanent plots were also established in each treatment. Vegetation sampling was performed in August 1978, 1979, and 1981, the first, second, and fourth growing seasons after treatments.

Above-ground biomass is estimated by components. The components were modified from Blair and Brunett (1976) and are: (1) grasses and grass-likes, (2) composites, (3) legumes, (4) other forbs, (5) vines (non-preferred by wildlife) and (6) woody flora by species. This separation permits estimating competition amounts by groups with differing control and response characteristics, as well as wildlife forage amounts. However, contrary to forage surveys, the total standing-crop of woody vegetation is estimated, rather than the current year's growth.

To minimize the biomass estimation variance, estimates should be made by one person. The training steps outlined by Pechanec and Pickford (1937) are helpful and should be followed. The first training involves the calibration of ocular estimates. They suggest that field trials be undertaken prior to actual sampling using a weighing balance. An appropriate balance weighs accurately to 2 grams and is suitably rugged for field use. Individual stems of composites and woody seedlings/sprouts are estimated, clipped and weighed for practice. Also, clumps or small mats of grass can be taken as units by which an average-size clump or mat is estimated and weighed and the process repeated until a close estimate is achieved. A reminder-card can be constructed showing approximate weights for heights of composites and woody stems, diameters of grass clumps, lengths of vines, and single rosettes of small plants. This ocular calibration procedure, based on vegetation units, can be re-employed each morning during the early field season to lend consistency to estimates.

In the next phase of training, sample plots should be examined and a small pocket calculator used to sum the estimates of the individual units counted and sized on the plot. A key to ocular estimates of standing-crop is that all individual units or plants must be seen. Seeing each part of a trailing vine and each small forb rosette requires a thorough examination. This becomes more difficult as the amount and complexity of the vegetation increases yearly on permanent plots and influences the choice of plot size.

Biomass can be estimated as green or oven dry-weights. Difficulties with changing moisture contents during a sampling season have been reported by Hilmon (1958) and resulted in costly procedures specifying continual sampling of plant moisture and adjustments of green-weight-estimates. In the current study, green-weight or oven-dry weight equations could be fitted equally well, as indicated by the R^2's in Table 1. Thus oven-dry weights were estimated directly, concuring with a similar modification by Blair (1958). Obviously, dry-matter is the main substance visualized in these ocular estimates while the day-to-day variation in moisture content is not readily perceived. This recognition suggests another training aid. Specifically, during the early field season, the estimator should check daily plot estimates on clipped-plots by weighing the clipped samples in the evening and checking his estimates on a green-weight basis, making adjustments as indicated the following day. The close correlation between green and oven-dry weights permits these green-weight checks even though oven-dry based regressions will be calculated.

Training of the clipping crew must include accurate differentiation of species into component groupings. Inconspicuous plants or new species should be tagged or communicated in some manner to the crew when the estimator is not present at clipping. Stubble heights of 2.5 cm are usually specified and all clipped material must be placed in appropriately marked paper bags for oven drying.

These steps were performed in this study. Bags with plant material were oven-dried at 750C until no further weight-loss occurred, a procedure requiring up to a week of drying for woody stems greater than 3 cm in diameter and a minimum of 24 hr for moist herbage.

Developing the Regressions

The ocular estimates of biomass from the first sampling stage are related to the measured biomass using standard linear regression techniques. The X-values are "estimated weights" and the Y values, "actual weights." These regression equations are then used to correct all data from the "estimated-only" plots. Linear regressions through the origin as specified by Wilm et al (1944) can be used. The intercept at the origin is a logical assumption, discounting mistakes such as miscomnunications between estimator and clipping crew.

The various aspects of fitting a straight line through the origin are covered most completely, but still briefly, by Snedecor and Cochran (1967) on pages 166 to 171. A test of the null hypothesis that the regression lines do, in fact, go through the origin can be performed. This test was perfomed on first-year's data from the Piedmont study. T-values are presented in Table 1. The non-significant (n.s.) t-values at the 5 percent level of probability show the null hypothesis should not be rejected, and the regression lines generally go through the origin, both the estimated vs green weight regressions and the estimated vs oven-dry weights.

The linear regressions through zero in this study were calculated using the common least-squares method of calculating an unbiased regression coefficient by $b = \Sigma XY/\Sigma X^2$. This assumes that the variance of Y is constant as X increases, which has been impossible to test so far. This is especially difficult since the X's are estimated and have the most variance, not the Y's, reversing the general case given in most statistic textbooks. Figure 1 shows the point-scatter for the fourth-year sampling and these data give little indication that the variance in Y increases greatly with an increasing X. Blair (1958) reported that the variance of Y does increase with an increasing X when sampling browse and used $b = \bar{Y}/\bar{X}$ to estimate the regression coefficient. A scatter plot of data points should be constructed to determine which method is best suited for a study. If the variance of Y increases as X increases, then $b = \bar{Y}/\bar{X}$ should should provide the best unbiased estimate of b.

Second-stage Sampling

In the second stage of sampling, biomass is ocularly estimated on the permanent plots in a manner identical to that used on the 'clipped' plots. An aid to estimating exceptionally large woody plants is to clip a nearby equal-sized plant away from the plot and weigh it. Disturbance during examinations must be minimized on permanent plots. Plot dimensions must allow the estimator to stand on the outside and parting vegetation with a stick, see all individual plants. Thus, the 2 m square used in the

Table 1. Comparison between first-year regressions using estimated weight vs actual green weight or oven-dry weight showing the coefficients of determination and the t-statistics testing the H_0 that the regression goes through the origin.

Component	Estimated Weight vs Actual Green Wt		Estimated Weight vs Actual O.O. Wt	
	R2	t	R2	t
Grasses & Grass-likes	.81	1.63 n.s.	.80	1.98 n.s.
Composites	.a7	.22 n.s.	.82	.38 n.s.
Legumes	.99	.97 n.s.	.97	.41 n.s.
Other forbs	.97	1.23 n.s.	.94	1.30 n.s.
Vines	.97	.10 n.s.	.96	.47 n.s.
Trees & shrubs:				
Quercus marilandica	.99	.30 n.s.	.99	.31 n.s.
Liquidambar styraciflua	.92	.91 n.s.	.80	1.02 n.s.
Rubus spp.	1.00	1.11 n.s.	1.00	1.00 n.s.

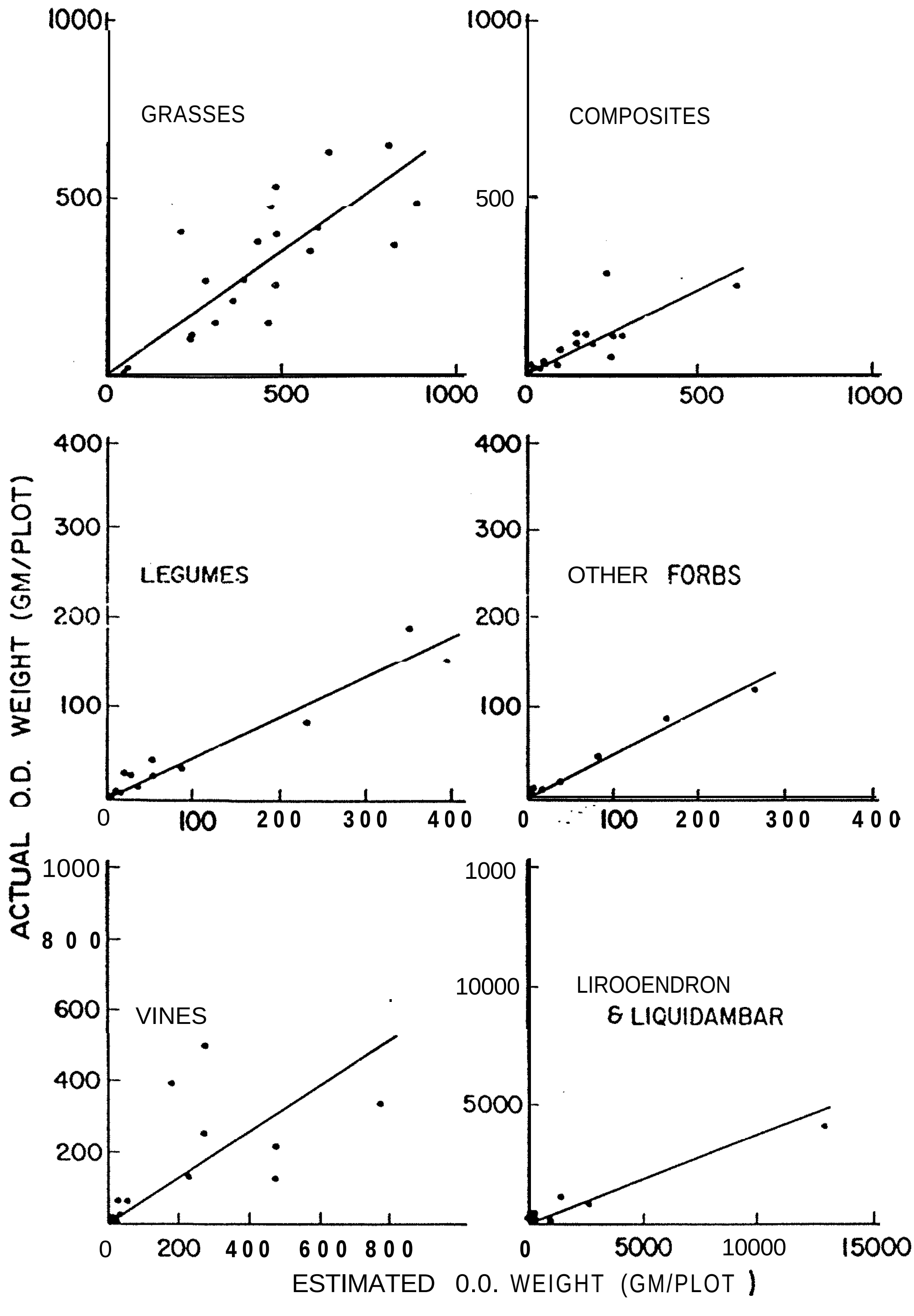

Figure 1. Data points and calculated regressions through the origins.

Piedmont example approximate; the maximum dimension and larger plots would need to be rectangular. Plots of equal size must be used in the first- and second-stage sampling.

The ocular estimates of biomass on permanent plots are adjusted by multipling by the appropriate regression equations for each vegetation component and then summed.

PIEDMONT EXAMPLE

Regression coefficients calculated in the Piedmont study using $b = \Sigma XY/\Sigma X^2$ are presented in Table 2. The R^2's presented in Table 2 were computed in the normal manner using the least-squares regression calculated before forcing through the origin. Most values are close to 1.00, indicating that a linear regression explains most of the variation in Y. Woody species were grouped by similar life-form (growth habit) with 13 different regressions calculated. This many groups may not be necessary unless the differences in regression coefficients suggest that actual estimation peculiarities exist with each group. For example, Blair (1958) found it beneficial to group browse species by similar moisture cootents.

An inspection of the R^2's also indicates groups that were difficult to estimate and those which became more difficult as the vegetation developed. The lower R^2's of the grasses and grass-likes certainly reflect the difficulty with estimating this group which has numerous species and various life-farms, e.g., carpets, clumps, and presence or absence of seed stocks. Estimation of composites in the fourth year was hindered by extensive woody vegetation on plots. Vines became increasingly difficult to estimate due to masking as vegetation developed and to the increasing woody and more dense nature of Vitis spp., the main genus.

Predicted biomass estimates and actual biomass values are shown plotted in Figure 2 for the three sampling years. This indicates the estimating capabilities for this method. The dashed lines indicating $\pm$ 20 percent of the actual biomass, shows 28, 20, and 20 percent of the first, second, and fourth year estimates, respectively, exceed these limits. Thus, the limitations of this method are apparent from this example. More of an index of competition amounts is gained, not the precise quantities. But still, the time required for estimating a plot compared to clipping a plot is 5 to 15 percent. Six to ten plots can be estimated while one is being clipped. Figure 2 shows that even though the biomass was increasing, the ability to estimate apparently improved from the first to the fourth year.

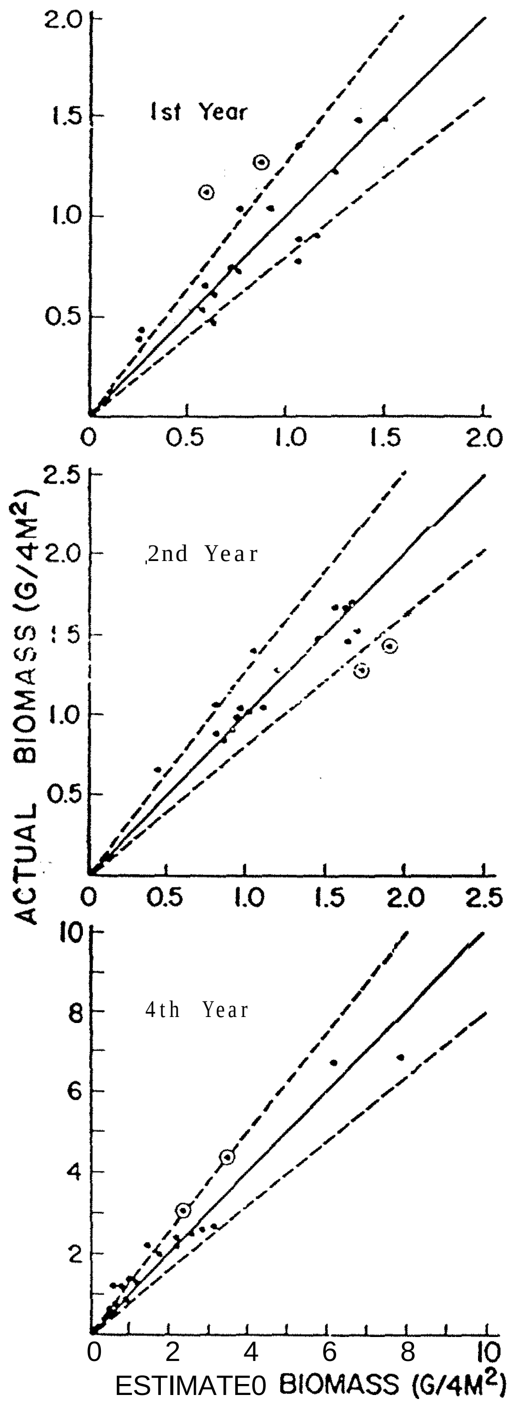

Figure 2. Estimated biomass plotted with the actual biomass. Dashed lines show $\pm$ 20 percent. Circled points indicate the first two plots estimated each field season.

Table 2. Regression coefficients and coefficients of determination by component group and year.

Component	1st Year b	1st Year R^2	2nd Year b	2nd Year R^2	4th Year b	4th Year R^2
1. Grasses and grass-likes	.49	.64	.71	.81	.69	.57
2. Composites	.45	.82	.45	.84	.47	.64
3. Legumes	.36	.94	.52	.94	.44	.94
4. Other forbs	.48	.88	.45	.89	.48	.98
5. Vines	.61	.96	.77	.87	.63	.59
6. Rhus radicans, Smilax spp.	.56	.84	.41	.92	.57	.91
7. Rubus spp., Rosa spp. Pteridium aquilinum	.61	1.00	1.12	.98	.41	.59
8. Vaccinium spp., Viburnum spp.	.63	.90	.51	.99	.84	.91
9. Calycanthus florida Callicarpa americana, Ceanothus americanus Hypericum spp.	.52	1.00	.53	.96	.69	.99
10. Rhus galbra, R. copallina Aralia spinosa, Hydrangea spp. Sambucus canadensis	.73	1.00	.41	.92	.58	.95
11. Quercus spp.	.64	.99	.65	1.00	.33	.85
12. Carya spp.	.55	.98	.91	.99	.48	.94
13. Liquidambar styraciflua Liriodendron tulipifera	.48	.90	.49	.98	.41	.98
14. Nyssa sylvatica, Ostrya virginiana Diospyros virginiana	.57	.95	.60	.96	.92	.98
15. Prunus serotina, Morus alba Sassafras albidum, Celtis occidentalis Oxydendron arboreum Crataegus uniflora, Tilia americana	.70	.92	.61	.96	.56	.84
16. Cornus florida	.54	1.00	.98	.97	.71	1.00
17. Acer rubrum	.76	.86	.63	.98	.68	.89
18: Pinus taeda, Juniperus virginiana	.57	.95	.77	.99	.54	.91

Table 3. The percent of the predicted observations that were within plus-or-minus 10, 20, and 50 percent of the actual biomass for the 1978 and 1981 plots.

Component	1st Year			4th Year		
	10%	20%	50%	10%	20%	50%
	----------------------------percent---------------------------					
Grasses	20	37	73	5	20	70
Composites	21	39	71	16	47	74
Legumes	32	52	79	6	56	72
Other forbs	29	53	82	38	24	87
Vines	4	17	57	12		59
Rubus spp.	73	73	91	16	44	69
Liquidambar Styraciflua	21	57	93	6	25	50

An indication of the ability to estimate the different vegetation components is given in Table 3. Components can be estimated most consistently only to plus-or-minus 50 percent of the actual biomass. However, most of the values exceeding plus-or-minus 50 percent are for smaller biomass quantities. The larger quantities are closer to the actual. The summing process to obtain plot totals appears to average the over and under estimates of components to yield estimates closer to the actual (Fig, 2).

An alternate approach was examined using the fourth-year data. Instead of adjusting individually the components on plots, the adjusted plot estimates were regressed against the actual biomass values. Then the plot estimates were adjusted using this regression. This was performed to see whether a simplified method using only one biomass estimate (a sum of unadjusted components) per plot would have estimating value. Thus, a confidence interval was calculated (Neter and Wasserman 1974) for a *new* observation (an estimated-only plot) using both the component-adjusted and the total-adjusted approaches. For a new plot with 1000 g biomass, the component-'adjusted method gave a 20 percent confidence interval of ± 674 g and the total-adjusted gave ± 912 g. For this data set, the component-adjusted method, as outlined in this paper, gave an estimate with a smaller confidence interval. Adjusting the estimates by component added to the estimating process.

With this method an estimate of the woody and herbaceous biomass surrounding a pine seedling on a permanent plot can be obtained. Most of the estimator's bias is controlled by the regression process; however, both care and consistency are required in making the ocular estimates. And often these estimates must be made in difficult and trying field situations. Experience with this approach can enhance consistency and yield estimates that are reliable within definable bounds.

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