Correlation of crown features to growth rates in natural forests of Puerto Rico[*]

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COMPENDIO

El diámetro, la profundidad, el área y el volumen de la copa, así como el diámetro al pecho y la altura de los árboles, todos medidos en 1975, correlacionaron en varias instancias con el previo incremento periódico anual, por medio de regresiones lineales, en bosques de edad variable y de multiplicidad de especies en Puerto Rico.

Las relaciones entre diámetro de la copa y diámetro al pecho para cuatro especies del dosel, tanto en el bosque seco como en el húmedo, en suelo de piedra caliza, así como en un bosque muy húmedo montano, resultaron lineales. Ellas se redujeron desde los bosques xerofíticos a través de los bosques montanos hasta los bosques pluviales en Puerto Rico y Dominica.

Introduction

MOST tropical forest species have a disappointingly slow girth increment because of small crowns, inferior crown positions, localized crowding, and senescence (2). Several studies conducted in Puerto Rico during the last 30 years confirm slow diameter growth over a wide range of environmental conditions. Periodic annual dbh increment (PAI) in climax lower montane and montane forest was 0.10 cm/yr (14) with most species in the lower montane forest <0.50 cm/yr (4, 7, 10, 11), and most species in the montane forest ≤ 0.10 cm/yr (10, 11). Comparisons of PAI by crown classes usually yielded the sequence: dominants $\geq$ codominants $>$ intermediates $>$ suppressed stems (4, 7, 14), with PAIs rarely more than 0.25 cm/yr. Secondary lower montane forests grew faster than climax stands (14), but the PAI did not exceed 0.35 cm/yr.

Wadsworth (15) in his study of 200 slow and fast-growing trees concluded 1) trees of any size of crown class could grow rapidly, 2) several species showed a site preference and generally did not achieve rapid growth elsewhere, and 3) height and diameter growth appeared correlated. He also noted that 4) a tenth of the rapidly growing trees were within 3 m of rotten stumps, 5) certain species were disproportionately represented among the fast-growing stems, and 6) slow growth was frequently related to diseased or damaged crowns.

Many of the above conclusions suggest that the capacity of trees to use available light may account for most of the differences in PAI on a given site. First, dominant, codominant, and well-exposed intermediate trees can grow fast. This may be attributable to crown size as well as crown class. Second, the species disproportionately represented among the fast-growing individuals were usually secondary with spreading crowns capable of rapid growth when space is available. Third, proximity to fallen trees or rotten stumps may indicate release from adjacent competition. Finally, secondary forests, because they are generally less developed structurally, allow more light to enter the stand.

The purposes of this study are to explore linear relations between crown and tree dimensions measured in 1976 and previous PAIs for periods ranging from 8 through 14 years, to determine crown diameter/bole diameter ratios (CD/BD) for selected canopy species in dry and moist coastal forests, and a wet montane forest, and to compare these ratios with other published CD/BD ratios. Since the independent parameters span a comparatively short period of time (≤ 14 years) in slow-growing forests (PAI ≤ 0.11 cm/yr), it was assumed that net changes in crown and dbh dimensions would be small and current measurements would closely approximate conditions throughout the period. There is a future need, of course, for crown dimensions as predictive measures of PAI.

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Table 1.—Summary of Species Data by Crown Class, 1975.

Crown class	Nº Replications	Tree Height (m)	dbh (cm)	PAI (cm/yr)	CD/BD Ratio
B. buceras (Guánica)					
D	1	9.4	13.2	0.05	51.2
CD	8	8.9	10.7	0.03	32.0
I	4	7.4	9.4	0.02	32.5
S	1	7.9	6.6	0.04	29.5
TOTAL/MEAN	14	6.4	10.2	0.03	33.4
F	—	3.67*/a	4.76*	0.81	1.51
C. diversifolia (Cambalache)					
D	1	10.4	13.2	0.25	20.3
CD	10	8.9	10.6	0.07	26.0
I	16	7.1	7.9	0.06	28.2
S	3	6.0	5.8	0.04	30.8
TOTAL/MEAN	30	7.7	8.6	0.08	27.4
F	—	9.86**	6.22**	5.41**	0.77
T. retinosa (Cambalache)					
D	3	9.6	15.2	0.18	23.2
CD	6	4.7	8.9	0.09	26.5
I	7	2.5	6.8	0.06	22.0
S	—	—	—	—	—
TOTAL/MEAN	16	4.7	9.1	0.09	23.9
F	—	8.07**a/	14.62**	4.46*	1.43
T. resinosa (Maricao)					
D	1	10.1	23.9	0.15	19.9
CD	3	7.8	14.2	0.11	25.1
I	8	8.1	11.4	0.09	26.1
S	—	—	—	—	—
TOTAL/MEAN	12	8.2	13.2	0.10	25.4
F	—	3.77*	10.25**	0.41	0.40
M. chrysophylloides (Maricao)					
D	2	11.9	26.7	0.19	22.4
CD	3	9.8	14.7	0.13	25.2
I	6	9.0	12.4	0.12	29.6
S	3	6.1	5.8	0.02	33.9
TOTAL/MEAN	14	9.0	13.5	0.11	28.6
F	—	6.33**	11.20**	1.97	2.12

a/ One asterisk indicates significance at 0.05 level; two asterisks, at 0.01 level.

The study areas

The Guánica dry limestone forest of southwestern Puerto Rico receives about 750 mm/yr of rain which are quickly absorbed by the porous soils Potential evapotranspiration exceeds rainfall by 1270 mm/yr

The Cambalache wet limestone forest in the north-central part of the island receives about 1400 mm/yr of rain, which as at Guánica, are rapidly absorbed by the porous soils Potential evapotranspiration exceeds rainfall by 500 mm/yr.

The Maricao forest in the west-central portion of the Cordillera Central is a wet montane habitat on serpentine which receives about 2600 mm/yr of rain. Precipitation exceeds evapotranspiration by 1520 mm/yr.

The canopy in all of the forests is low, generally not over 10 m at Guánica, 18 m at Cambalache, and 12 m at Maricao.

Methods

Canopy species with stems in at least 3 of the 4 crown classes, and with 12 or more replications by site were selected for study Their most common height and diameter dimensions at maturity, forest types of most frequent occurrence, and range are given by Little and Wadsworth (6) None is large; all are common to the dry or moist limestone forests, and/or wet montane forests in Puerto Rico.

During 1976, the following measurements were taken or derived for all stems: 1) dbh, 2) crown class, 3) crown diameter (mean of the crown's longest horizontal dimension and the horizontal dimension perpendicular to and bisecting the former); 4) crown depth (the mean of 4 verticals through the crown, each located at half the distance between the intersection of the bisecting horizontal dimensions and the edge of the crown; 5) live crown length (the maximum length of the live crown); 6) total tree height; 7) crown area, assumed a circle, $= \pi$ (crown diameter$/2)^2$; 8) crown volume, assumed a cylinder, $=$ (crown area x crown depth); 9) CD/BD; and 10) live crown length/total tree height

Previous dbh measurements within these same stands had been made 14 years ago in Guánica, and eight years ago in Cambalache and Maricao.

Data analyses included standard ANOVAS and simple and multiple linear regressions

Table 2.—Summary of Simple and Multiple Correlation Coefficients of Selected Crown and Tree Parameters versus PAI for Four Species in Guánica, Cambalache, and Maricao Forests 1/

Row 2/	Crown or Tree Parameter(s) Used in the Regression Equations	Gúanica Forest *Bucida buceras*	Cambalache Forest		Maricao Forest	
			Coccoloba diversifolia	*Terebraria resinosa*	*Terebraria resinosa*	*Micropholis crysophylloides*
	(n, Critical r at α = 0.05) 3/	(14, 0.532)	(30, 0.361)	(16, 0.497)	(12, 0.576)	(14, 0.532)
1 a	Diameter of crown	0.542*	0.414*	0.807**	0.752**	0.692**
b	Diameter of crown	0.721**	0.566**	0.520*	0.601*	0.744**
c	Depth of crown	0.101	0.657**	0.801**	0.505	0.473
d	Depth of crown	0.587*	0.464**	0.564*	0.532	0.643*
e	Area of crown	0.604*	0.352	0.760**	0.727**	0.660**
f	Volume of crown	0.597*	0.607**	0.714**	0.749**	0.531
g	dbh of bole	0.444	0.620**	0.840**	0.560	0.660**
h	Height of tree	0.533*	0.716**	0.801**	0.543	0.693**
2	Initial dbh of bole	0.335	0.475**	0.752**	0.480	0.591*
	(n, Critical R at α = 0.05)	(14, 0.618)	(30, 0.446)	(16, 0.608)	(12, 0.697)	(14, 0.648)
3 a	Diameter and Depth of crown	0.641	0.736**	0.590	0.752*	0.705*
b	Area and Depth of crown	0.701*	0.721**	0.829**	0.780*	0.683*

1/ All correlation coefficients, regardless of significance, are presented for comparative purposes Coefficients significant at 95% level are indicated with single asterisk; at 99% level, with double asterisk. *Correlation coefficients:* 1b and 1d are for equations of the form $\ln y = b \ln X + \ln a$ where y = PAI, X = the crown or tree parameter; 3a and b for equations of the form $Y = B_0 + B_1 X_1 + B_2 X_2$; and remaining for equations of the form $Y = B_0 + B_1 X_1$

2/ All parameters in Rows 1a-h and 3a b were measured in 1975; dbh in Row 2 was measured at beginning of study

3/ n = number of replications; r and R = critical correlation coefficient at stated α = 0.05 and appropriate degrees of freedom.

Results and discussion

For all species, the ANOVAS for tree dbh and tree height show significant differences by crown class while PAI is significant in only two instances (Table 1). The Guácima trees had no changes in crown class during 14 years; Cambalache, 22 percent alterations in eight years; and Maricao, 37 percent in eight years. Most changes involved adjacent classes. Crown class categories were more stable in Guánica, probably due to slower PAIs.

For simple linear regressions by species (Table 2, rows 1 a, c, e, f), crown diameter correlates significantly with PAI in 5 of 5 instances; crown depth, 2 of 5; crown area, 4 of 5; and crown volume 4 of 5. Tree dbh and height both correlate with PAI in 3 and 4 instances, respectively. For the transformed data (Table 2, rows 1 b, d), crown diameter correlated in all 5 cases, and crown depth, in 4 of 5.

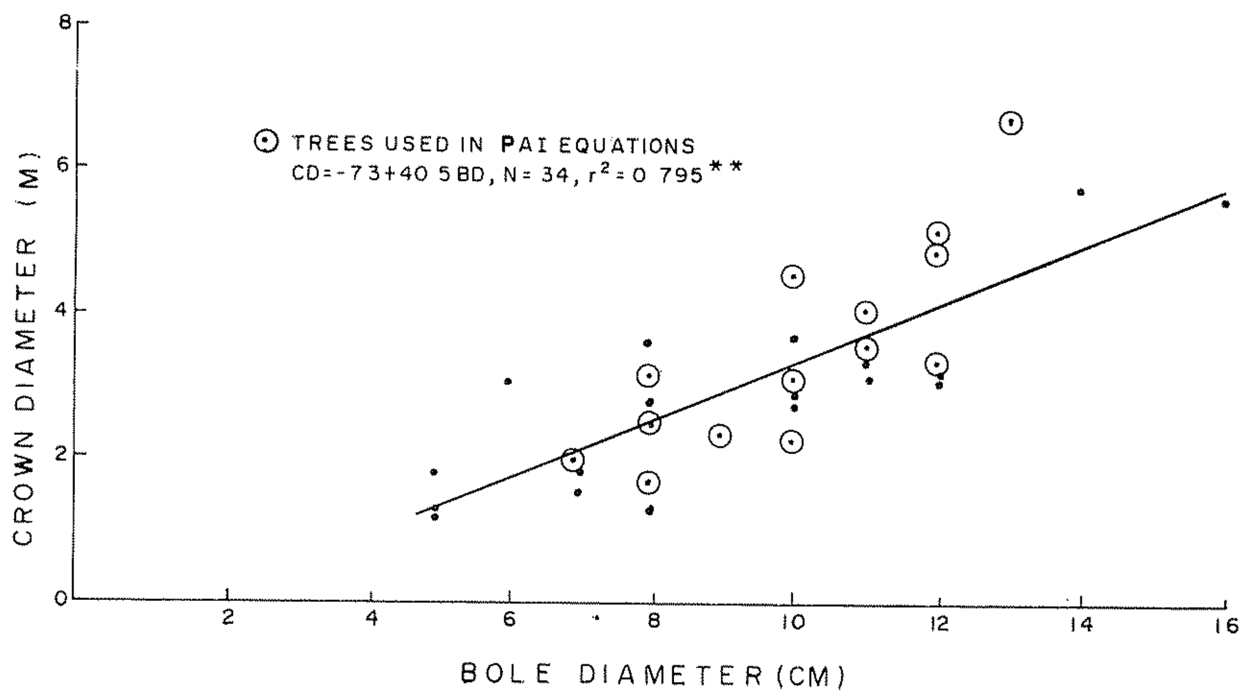
Crown class and dbh, the only parameters recorded initially, have predictive value for PAI: dominants > codominants > intermediantes > suppressed, with the exception of one suppressed stem in Guanima (Table 1); dbh correlated significantly with PAI for both species in Cambalache Forest, and *M. chrysophylloides* in Maricao Forest (Table 2 row 2).

Multiple linear regressions (Table 2, rows 3a, b) demonstrate positive correlation in 8 cases of 10. However, inclusion of the second regressor variable decreased the amount of unexplained variation only for *B. buceras* in Guánica and *C. diversifolia* in Cambalache forests.

None of the linear regressions of CD/BD ratios versus PAI by species was significant, and only one regression of live crown/tree height versus PAI was significant. This is understandable since it is the actual photosynthetic leaf area reflected in crown dimensions which affects PAI. Smaller trees may have slightly larger CD/BD ratios in several instances, yet may be suppressed (Table 1). Van Laar (13) suggested that the growth of individual *Pinus radiata* trees depended primarily upon past growth, quantitatively expressed through the bole diameter or crown yength of the tree.

Linear CD/BD equations are given for each species by forest type in Figure 1 a-c. All regressions were found significant at the 99 percent level. For Maricao and Cambalache forests, individual species regressions were compared and found not significantly different, and therefore combined by site.

CD/BD ratios are useful in forest inventories and in planning silvicultural practices. In an exhaustive study of 18 stands with climatic, elevational and site differences, principally in Puerto Rico, Pérez (9) observed that xerophytic trees had larger ratios than lower montane and montane trees. His ratios agree with ours. Bell (1) in Dominica reported ratios of 21:1 for timber species of the lower montane rainforest, and 18:1 for



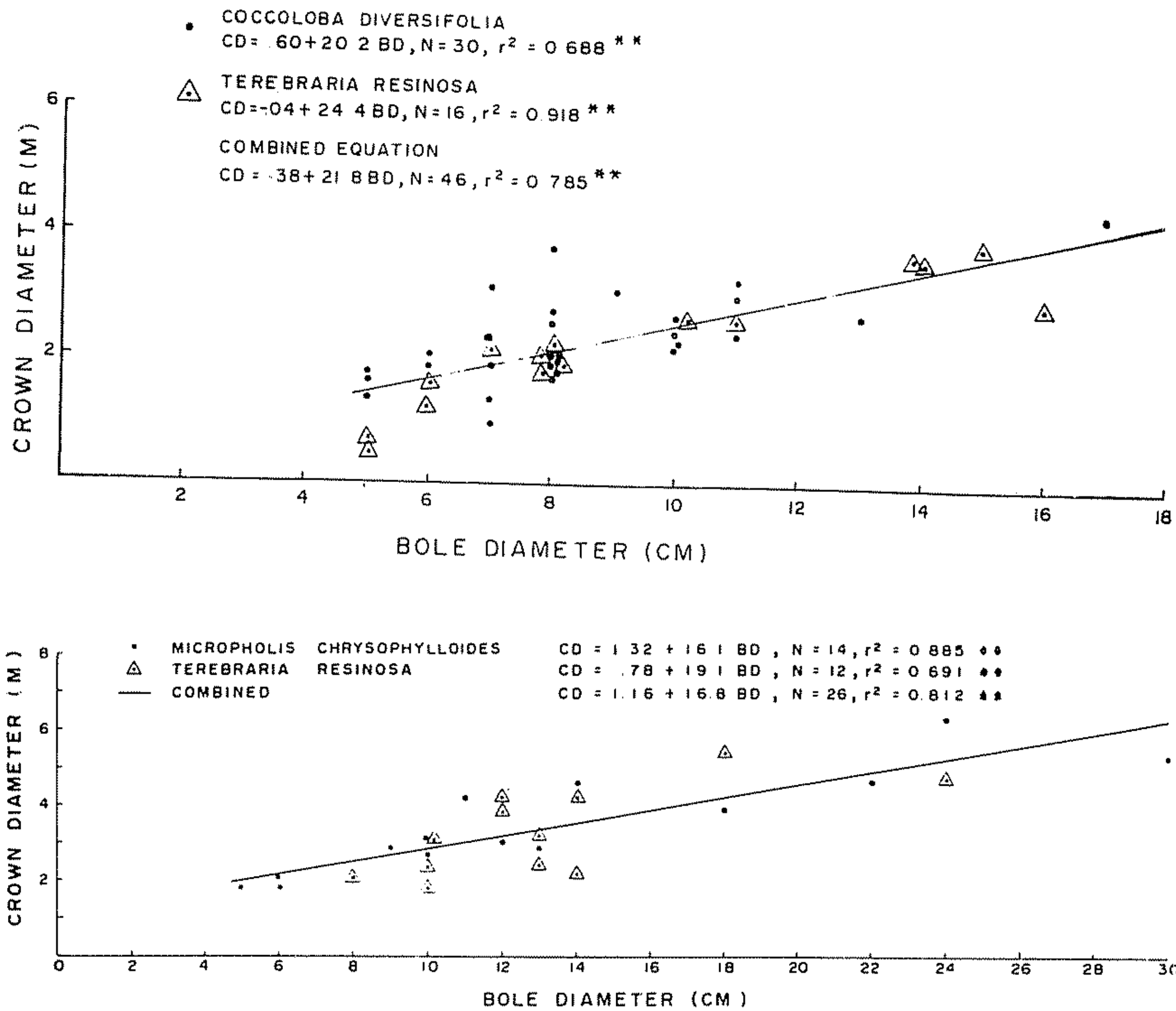


Fig. 1.—*Crown Diameter/Bole Diameter Relationships.* *(A)* Bucida buceras in *Guánica Forest* *(B)* Coccoloba diversifolia *and* Terebraria resinosa *in Cambalache Forest and (C)* Micropholis chrysophylloides *and* Terebraria resinosa *in Maricao Forest.*

timber species in the rainforest. In general, ratios in Puerto Rico and Dominica appear to decrease gradually from about 35:1 in xerophytic areas to about 18:1 in rainforests. Ratios for comparable forest types in continental areas appear to be larger (2, 5, 12).

The "little developed emergent story, small crowns, small crown-to-stem ratios, numerous stems and small photosynthetic surface per stem" characteristic of the montane forests of Puerto Rico and Dominica, may be adaptive to hurricanes (8). These same features may partially account for the slow PAIs observed and impose limitations on management since thinnings designed to accelerate PAI may or may not generate a rapid crown growth response, and most assuredly will expose the stands to increased hurricane damage.

Summary

Crown diameter, crown depth, crown area, crown volume, tree dbh and tree height measured in 1975 were found to correlate in several instances with previous periodic annual diameter increment through linear regressions in uneven-aged, species-rich stands in Puerto Rico.

The relationship between crown and bole diameters for four canopy species in dry and moist limestone forests, and a wet montane forest were found to be linear. Ratios decreased from xerophytic through montane and rainforest habitats in Puerto Rico and Dominica.

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Notas y Comentarios

Científico de las Galápalos honrado por su Universidad

En ocasión del 129º aniversario del Austin College de Texas, Craig George MacFarland, actualmente Jefe de la Unidad de Areas Silvestres y Cuencas del Programa de Recursos Naturales Renovables del CATIE, recibió un grado honorario de Doctor en Ciencias

Un científico de nota en ciencias naturales, McFarland ha sido desde 1974 Director de la Estación Científica Charles Darwin en las Islas Galápalos, completando allí estudios sobre las tortugas gigantes de esa zona, estudios que había iniciado en 1968. En las Galápalos, realizó también numerosos estudios ecológicos aplicados a la conservación y manejo, y desarrolló varios cursos de posgrado para naturalistas, sobre la historia natural y conservación de la flora y fauna de las Islas Al mismo tiempo asesoró al gobierno ecuatoriano en parque nacionales y zonas marinas. En 1978 fue contratado por el Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) en Turrialba, Costa Rica

Publicaciones

Revista Colombiana de Ciencias Agropecuarias En 1978 se iniciado la publicación de la *Revista Colombiana de Ciencias Agropecuarias*, órgano del Colegio de Médicos Veterinarios y de Zootecnistas de Antioquía (Colveza) Reemplaza a *Revista Colveza* y al *Boletín Científico*, de cuya fusión ha resultado Está destinada a la información científica relacionada con la medicina veterinaria y la zootecnia, como también a los aspectos concernientes a estas dos disciplinas desde el punto de vista profesional y gremial De periodicidad trimestral, el director es Jorge E. Ossa, y la dirección, Apartado Aéreo 5040, Medellín, Colombia En el ejemplar que tenemos a la mano (vol 1, Nº 3) notamos que se usa el punto tanto para separar los decimales como los millares y los millones; ha desaparecido la coma decimal, que es normativa para todos los idiomas excepto el inglés No hay uniformidad en la colocación de las tablas que se colocan de costado; a veces la cabeza va correctamente a la izquierda (pp 208 a 214), otras veces va a la derecha (228 a 230) Las abreviaturas de pesos y medidas no siguen las normas del SI

Publicaciones

Ciencias Agropecuarias Con fecha octubre de 1918 ha aparecido un revista, *Ciencias Agropecuarias*, órgano del Instituto de Investigación Agropecuaria de Panamá (IDIAP), la que presentará trabajos de investigaciones científicas llevadas a cabo por técnicos nacionales y extranjeros que se dedican a las ciencias agrícolas y pecuarias. El primer número tiene ocho artículos y dos notas de investigación, los que tratan de temas como fertilización de pastos (4 trabajos), alimentación del ganado (4 trabajos), cultivo de maíz y enfermedades del tomate (1 de cada uno) La periodicidad será inicialmente irregular La editora es Elizabeth de Ruiloba y la dirección es: IDIAP, Apartado 58, Santiago, Veraguas, Panamá

Publicaciones

Yuca, Boletín Informativo El Proyecto de Información sobre Yuca, en el Centro Internacional de Agricultura Tropical, (CIAT), está publicando *Yuca, Boletín Informativo*, destinado a servir de canal de comunicación entre los que trabajan en yuca Se publica desde 1977, semestralmente, tanto en castellano como en inglés *(Cassava Newsletter)* y contiene notas técnicas, noticias de eventos, informes de progreso y documentación La editora es Trudy Brekelbaum y la dirección es: CIAT Apartado Aéreo 67-13, Cali, Colombia