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A Description of FORICO, a Tropical Gap Dynamics Model of the Lower Montane Rain Forest of Puerto Rico

T. W. Doyle

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1875

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A DESCRIPTION OF FORICO, A TROPICAL GAP DYNAMICS MODEL OF THE LOWER MONTANE RAIN FOREST OF PUERTO RICO

T. W. Doyle

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ABSTRACT

DOYLE, T. W. 1982. A description of FORICO, a tropical gap dynamics model of the lower montane rain forest in Puerto Rico. ORNL/TM-8102. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 54 pp.

The FORICO model, a gap dynamics model of the lower montane rain forest in Puerto Rico, is documented. It simulates gap formation and replacement of a 1/30 ha forest stand. The model increments the growth of individual trees, introduces new seedlings, and considers the death of trees on a per annum basis. This stochastic gap model also simulates the return frequency and stand damage effects of hurricanes common to West Indian forests. Key autecological parameters of 36 common tree species are used as input to the model.

Model subroutines are illustrated and described in their order and function. A listing of the FORICO model and a sample of model output is included.

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INTRODUCTION

Over the past 10 years, systems modeling has been particularly important in studying the long-term dynamics of forest succession which otherwise might require several human generations to observe directly. Because of the utility of the systems approach for this purpose, a myriad of mathematical models were constructed to simulate the successional dynamics of mixed species forests, mainly of temperature types. This paper documents a stochastic gap model, FORICO, developed for a lower montane rain forest on the lower slopes and ridges below 600 m in the Luquillo Experimental Forest in northeastern Puerto Rico. This model is the first of its kind designed for an American tropical forest system.

The FORICO model represents a modified version and tropical counterpart of the FORET model developed by Shugart and West (1977). The conceptual framework and modeling approach of these models was first put forth in the JABOWA model by Botkin et al. (1972). These stochastic gap models are designed to simulate the successional dynamics and competitive interrelations among individual trees on the specified spatial unit approximating a large gap opening. Gaps are modeled as the result of death and disturbance of canopy tree(s). These gaps are assumed to occur within an intact forest providing an adequate and equitable seed source. Natural succession and/or gap recolonization is modeled as a stochastic tree-by-tree replacement process. Gaps are also simulated as spatially homogeneous areas, wherein competitive effects from shading and crowding are evenly distributed for all trees over the entire stand (Shugart and West 1979).

MODEL DEVELOPMENT

FORICO, a forest simulator of Puerto Rico, was constructed by modifying the FORET model developed by Shugart and West (1977) to conform with the tree species and forest characteristics of the lower montane rain forest in Puerto Rico. This task involved an evaluation of the applicability of FORET's design, functions and parameters to simulate the gap phase dynamics of a tropical American forest. Major modifications included the recomputation of all model parameters and the incorporation of a model subroutine to consider the disturbance effects of hurricanes which are common to forests in the West Indies. Comparison of the differences between these models should indicate general dissimilarities in the properties and function of tropical and temperate systems. These contrasts of model functions and parameters are presented in the following description of the FORICO model.

MODEL DESCRIPTION

The FORICO model is a detailed forest simulator of natural gap succession of a lower montane rain forest on the lower slopes and ridges below 600 m in the Luquillo Experimental Forest in northeastern Puerto Rico. It simulates the gap formation and replacement process of individual trees on a circular 1/30-ha forest stand (Fig. 1). Key autecological parameters of 36 common tree species are used as input to the model (Table 1). Model processes, mainly tree birth, growth, and death, are expressed as functional relationships computed in yearly intervals. Tree growth is incremented in centimeters of diameter at breast height (dbh) as a function of tree size, crown position, and

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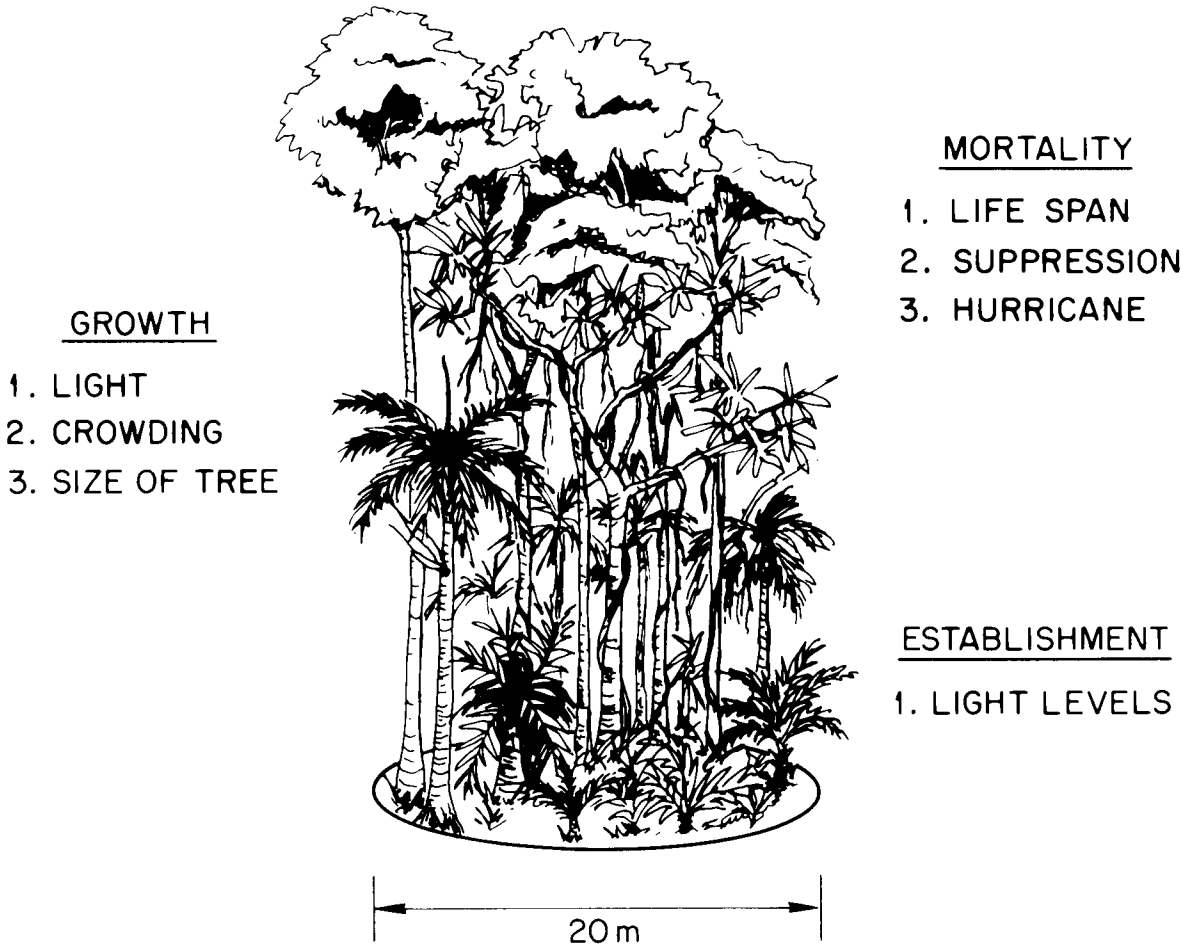

Fig. 1. Illustration of the simulated 1/30-ha forest stand, a circular plot 20 m in diameter, and the major model processes and factors affecting individual tree establishment, growth, and mortality.

Table 1. Species list and autecological parameters used in the FORICO model

Species name[a]	Dmax[a]	Hmax[a]	B_2	B_3	TOL[b]	AGE[c]	G[d]	Smin	Smax
Alchomea latifolia	46	1524	60.30	0.6554	2	58	240.19	0.05	0.12
Alchorneopsis portoricensis	46	1524	60.30	0.6554	2	56	246.40	0.05	0.12
Buchenavia capitata	122	2438	37.72	0.1545	2	120	182.85	0.05	0.12
Byrsonima coriacea	46	1829	73.56	0.7996	3	46	202.78	0.12	1.00
Casearia arborea	15	914	103.60	3.4533	3	47	175.37	0.12	1.00
Casearia Sylvestris	10	457	64.00	3.2000	2	44	99.00	0.05	0.12
Cecropia peltata	61	2134	65.47	0.5366	3	50	271.12	0.12	1.00
Cordia borinquensis	13	610	72.76	2.7988	1	43	131.99	0.004	0.75
Cyathea arborea	13	914	119.53	4.5976	3	17	461.89	0.12	1.00
Dacryodes excelsa	152	3048	38.30	0.1259	1	205	132.34	0.004	0.05
Didymopanax morototoni	46	1829	73.56	0.7996	3	52	267.65	0.12	1.00
Drypetes glauca	15	914	103.60	3.4533	1	56	147.19	0.004	0.05
Eugenia stahlii	30	1829	112.80	1.8800	1	103	154.85	0.004	0.05
Euterpe globosa	20	1524	138.70	3.4675	1	22	587.34	0.004	1.00
Guarea rumiflora	15	762	83.33	2.7777	1	41	169.56	0.05	0.12
Guarea trichiloides	91	2286	47.23	1.2095	2	121	169.56	0.004	0.05
Hirtella rugosa	8	610	118.25	7.3906	1	32	164.62	0.004	0.05
Homalium racemosum	61	2134	65.47	0.5366	2	107	178.41	0.05	0.12
Inga laurina	46	2134	86.82	0.9437	1	75	229.10	0.05	0.12
Inga vera	46	1524	60.30	0.6554	2	65	271.38	0.05	0.12
Laetia procera	30	2286	143.26	2.3877	3	86	228.60	0.05	0.12
Linociera domingensis	30	1829	112.80	1.8800	1	65	247.67	0.05	0.12
Manilkara bidentata	122	3048	47.72	0.1955	1	157	171.76	0.004	0.05
Matayba dormingensis	46	1829	73.56	0.7996	1	70	232.60	0.004	0.05
Miconia prasina	10	762	125.00	6.2500	2	26	257.17	0.05	1.00
Miconia tetrandra	30	614	92.46	1.5411	1	53	257.17	0.05	0.12
Ocotea leudoxylon	25	1524	110.96	2.2192	2	35	387.09	0.05	0.12
Ocotea moschata	76	2438	60.55	0.3983	1	76	57.03	0.004	0.05
Ormosia krugii	61	1829	55.47	0.4547	2	84	197.89	0.05	0.12
Palicourea riparia	8	457	80.00	5.0000	2	29	142.81	0.05	1.00
Psychotria berteriana	10	610	94.60	4.7300	3	28	195.68	0.05	1.00
Sapiura laurocerasus	61	1829	55.47	0.4547	2	167	99.00	0.05	0.12
Sloanea berteriana	91	3048	63.97	0.3515	1	118	226.08	0.004	0.05
Tabebuia heterohylla	46	1524	73.56	0.7996	3	79	206.75	0.05	0.12
Tetragastris balsamifera	46	2438	100.04	1.0874	1	169	125.87	0.004	0.05
Trichilia pallida	15	914	103.60	3.4533	1	254	32.23	0.004	0.05

[a]Taken from Little and Wadsworth (1964).

[b]Tolerance classes for each species drawn from Smith (1970).

[c]Computed from a supplemental program in Appendix A using the G constant and maximum size figures.

[d]Derived from tree growth data provided by the U.S. Forest Service Institute of Tropical Forestry (see Crow and Weaver 1977).

competitive effects (Fig. 1). Gaps are created from tree deaths caused by intrinsic mortality, suppression, and the impact of hurricane disturbances (Fig. 1). Gap recolonization is modeled as a stochastic tree-by-tree replacement process, based on the size of a newly formed gap and light levels at the forest floor (Fig. 1).

The simulated gap size was calculated for the tabonuco forest type following the rationale of Shugart and West (1979), who found the canopy spread of the largest tree specimen from a forest corresponded with the best model behavior and results. Utilizing a crown-stem diameter relationship (Perez 1970), a 1/30-ha stand size was estimated. This figure was confirmed with actual gap sizes of tree falls located in the tabonuco forest.

A flow diagram of model subroutines (Fig. 2) illustrates the order and function of these processes and support programs. Discussion of the derivation and utilization of the model parameters and functions by subroutines follows. Model results and validation are presented in a study by Doyle (1980).

Subroutine BIRTH

The BIRTH subroutine (Fig. 2) determines the species and number of new seedlings that are established on the plot each year. The process of gap recolonization and ingrowth in tropical moist forests is not well understood, although it is believed that light conditions and chance occurrence play a major role in species establishment (Webb et al. 1972). Eligibility of model species for recruitment is based on minimum and maximum light levels, Smin and Smax respectively, and a random probability which can be manipulated experimentally to simulate

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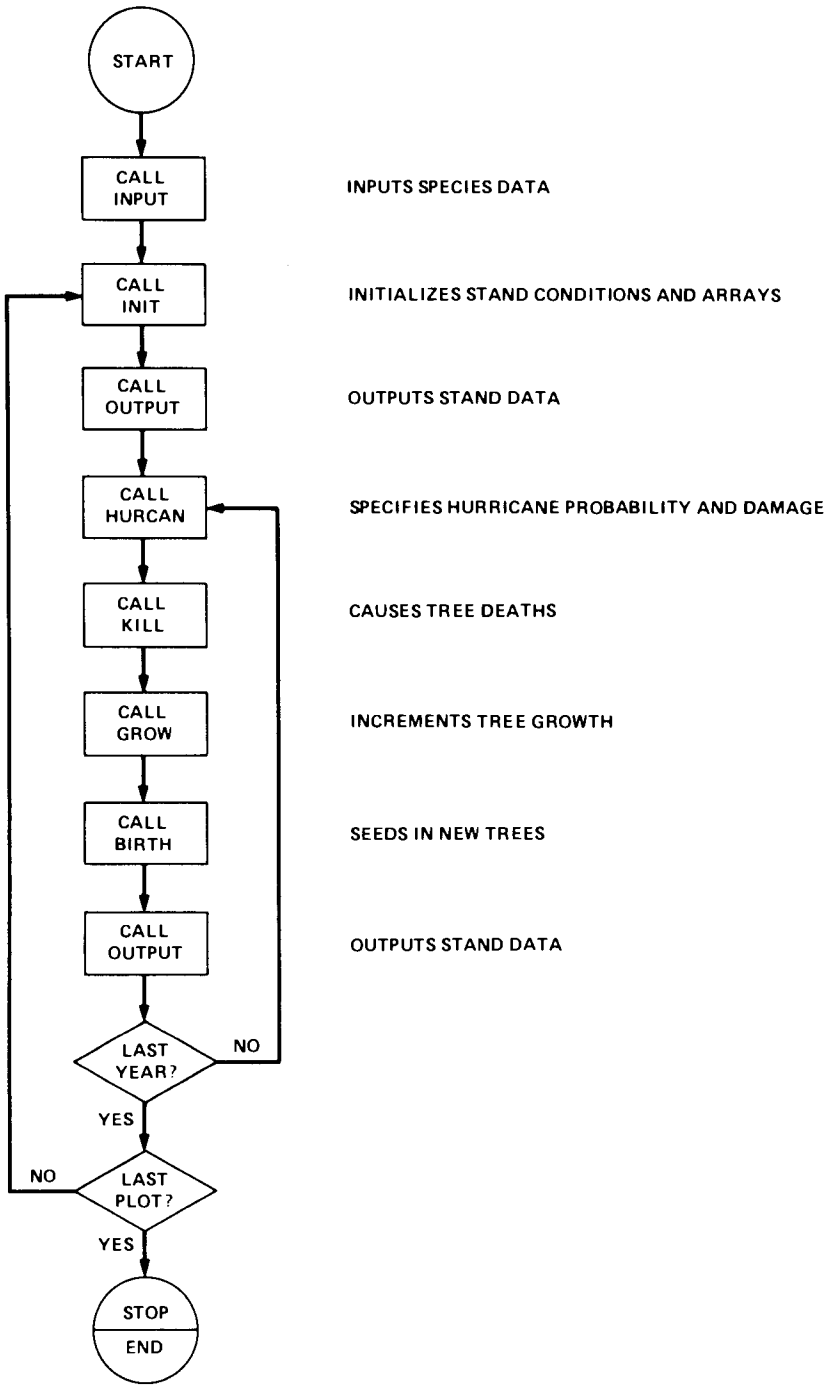

Fig. 2. Flow diagram of calls to subroutines in the FORICO model. The general function of each subroutine is listed beside the subroutine named in the box.

variable seeding effects (i.e., the presence of a mature seed tree on the plot).

Acevedo and Marquis (1978) and Brokaw (1979) independently conducted field studies which concluded that early secondary species in tropical wet forests require gaps greater than 150 m^2 to allow for successful colonization. Smin, the lower light limit required for establishment, was determined for pioneer species by calculating the diminished light level through an adjusted leaf area figure formulated when 150 m^2 of the average leaf area of 6.4 m^2/m^2 (Odum et al. 1963) on a stand size of 333 m^2 (1/30 ha) is removed. Smax, the maximum allowable light conditions for establishment, was set at 100% full sunlight for pioneer species. Late secondary species were given an Smax equal to the Smin of the early secondary species or pioneer species so as to allow each tolerance class a competitive edge within the light regimes that best suit their physiology and reproductive strategies. Smin for late secondary or shade-intermediate species represents an average of the Smin's set for both pioneer and climax species. Climax species or shade-tolerant species were given a Smax equivalent to the Smin for late secondary species. The Smin for climax species was set at the light compensation point determined for shade-tolerant species by Lugo (1970). To stock in new seedlings at the initiation of a simulation trail or following large gap openings from large tree falls or extensive hurricane damage, the model continues to enter new trees until a minimum leaf area of 2.5 to 3.0 m^2/m^2 (Ewel 1971) is attained. Ewel's study of early succession in the lower

montane rain forest in Puerto Rico found an average leaf area between 2 and 3 m^2/m^2 six months to a year after clearing.

Subroutine GROW

Tree growth is incremented yearly as a function of the size of the tree, the sum leaf area of taller trees, and the total biomass of all trees on the plot. Following the rationale of Botkin et al. (1972) [see also Shugart and West (1977)], optimal tree growth is described in the volumetric relationship,

$$\frac{d(D^2H)}{dt} = R\ LA\ (1 - \frac{DH}{Dmax\ Hmax}) \quad , \tag{1}$$

where R is a positive growth rate, LA is the leaf area of the tree, D is tree diameter at breast height (dbh), H is tree height, and Dmax and Hmax are the maximum diameter and height figures for each species (Table 1). This equation assumes that the annual production of tree growth is directly related to the amount of sunlight the tree receives in leaf area times the energetic cost of maintaining its size. Species' maximum diameter and height figures, taken from Little and Wadsworth (1964), were used to derive coefficients B_2 and B_3 (Table 1) of Ker and Smith's (1955) parabolic expression,

$$H = 137 + B_2\ D - B_3\ D^2 \quad , \tag{2}$$

for estimating tree height from tree diameter. Assuming that height growth ceases at a diameter of Dmax (i.e., H = Hmax; dH/dt = 0 when D = Dmax), the solutions for B_2 and B_3 are:

$$B_2 = 2(Hmax - 137)/Dmax \quad , \tag{3}$$

$$\text{and } B_3 = (Hmax - 137)/Dmax^2 \quad . \tag{4}$$

Employing this height-diameter relation and a growth parameter, G (Table 1), Eq. (1) can be solved to yield the diameter increment equation:

$$\frac{DD}{dt} = \frac{G\ D(1 - DH/Dmax\ Hmax)}{(274 + 3B_2\ D - 4B_3\ D^2)} \quad . \tag{5}$$

The species growth parameter, G, can be calculated for each species as either a function of its maximum growth rate [see Appendix of Botkin et al. (1972)] or its maximum age, as in the FORET model. Because aging of many tropical species is difficult and considered unreliable, maximum periodic annual increment figures, PAImax, were substituted in the equation:

$$G = (PAImax\ Hmax)/(0.2\ Dmax) \quad , \tag{6}$$

to solve for G (Table 1).

Maximum annual growth figures of native species were readily available from forest remeasurement data collected and provided by the U.S. Forest Service Institute of Tropical Forestry in Rio Piedras, Puerto Rico. Permanent stands were continually thinned and monitored over a 25-year period to allow optimum growth conditions and stand yield. Tree growth results for 18 commercially important species from

these plots were analyzed and discussed by Crow and Weaver (1977). Field conditions under which these 25-year growth data were obtained were such that competition for light, space, and nutrients was minimized, but the influence of climate was not. Consequently, the species growth constant, G, intrinsically incorporates the effect of climate on tree growth. This approach differs from the FORET model which includes a separate function based on temperature tolerance to simulate growth reduction due to climate.

To determine actual tree growth, however, the diameter increment equation (Eq. 5) is multiplied by growth inhibiting factors, r(AL), indicating the effects of shading, and S(BAR), signifying the influence from overcrowding:

$$\frac{dD}{dt} = \frac{G\ D(1 - DH/Dmax\ Hmax) \cdot r(AL) \cdot S(BAR)}{(274 + 3B_2\ D - 4B_3\ D^2)} \quad . \qquad (7)$$

Taking into account the stand structural profile, the FORICO model calculates the vertical distribution of tree heights in 0.1-m units and the sum leaf area above each tree. Leaf area is determined from a leaf area-diameter relationship (Fig. 3):

$$LA = a\ D^b \quad , \qquad (8)$$

where LA is the leaf area of a tree of diameter D, and a and b are constants with values of 0.4458 and 1.548, respectively, derived from biomass data in the appendix of Ovington and Olson (1970). The summed leaf area above each tree, obtained by adding the leaf area of all taller trees, is then used to estimate the amount of light available to

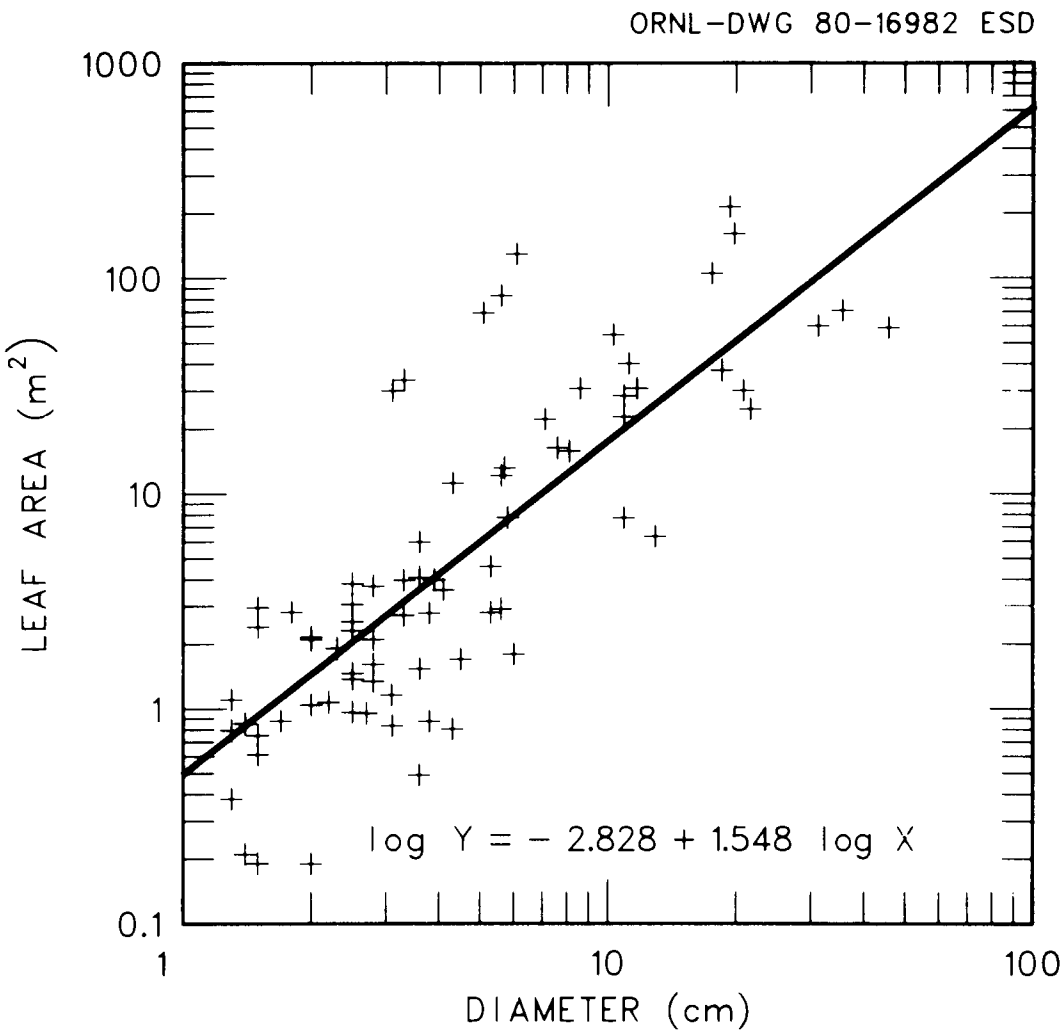

Fig. 3. Regression of leaf area with tree diameter.

each tree for growth due to shading. The distribution of photosynthetic light through the stand canopy is determined from the light extinction equation:

$$AL = PHI \cdot \exp(-K \cdot SUMLA) \quad , \tag{9}$$

where AL is the available light to each tree; PHI is the total incident radiation; K is the light extinction coefficient; and SUMLA is the summed leaf area above the tree (Kasanaga and Monsi 1954, Loomis et al. 1967, Perry et al. 1969). Total incident radiation, PHI, is set at 1.0 to represent optimum growth conditions at full sunlight. The light extinction coefficient, K, defines the relationship between decreased light intensity and the summed leaf area, SUMLA. Odum (1970) estimated a K value of 0.60 for a forest site near El Verde, Puerto Rico. An alternate calculation by the author, based on measured light levels from another site in this Puerto Rican rain forest (Johnson and Atwood 1970), confirmed a K value of 0.60. Figure 4 contrasts the light extinction curves of the FORICO model for a tropical evergreen forest and the FORET model of a temperate deciduous forest with a K value of 0.25.

After determining the amount of light available to each tree (AL), scaled to 1.0 at maximum sun exposure, the model computes the growth reduction, r(AL), associated with decreased photosynthetic potential under shaded conditions from the following expressions:

$$r(AL) = \begin{cases} 1.0 - \exp[-47.22(AL - 0.004)], \text{ for } TOL = 1 \\ 1.46\ \{1 - \exp[-1.24(AL - 0.03)]\{, \text{ for } TOL = 3 \end{cases} \quad , \tag{10}$$

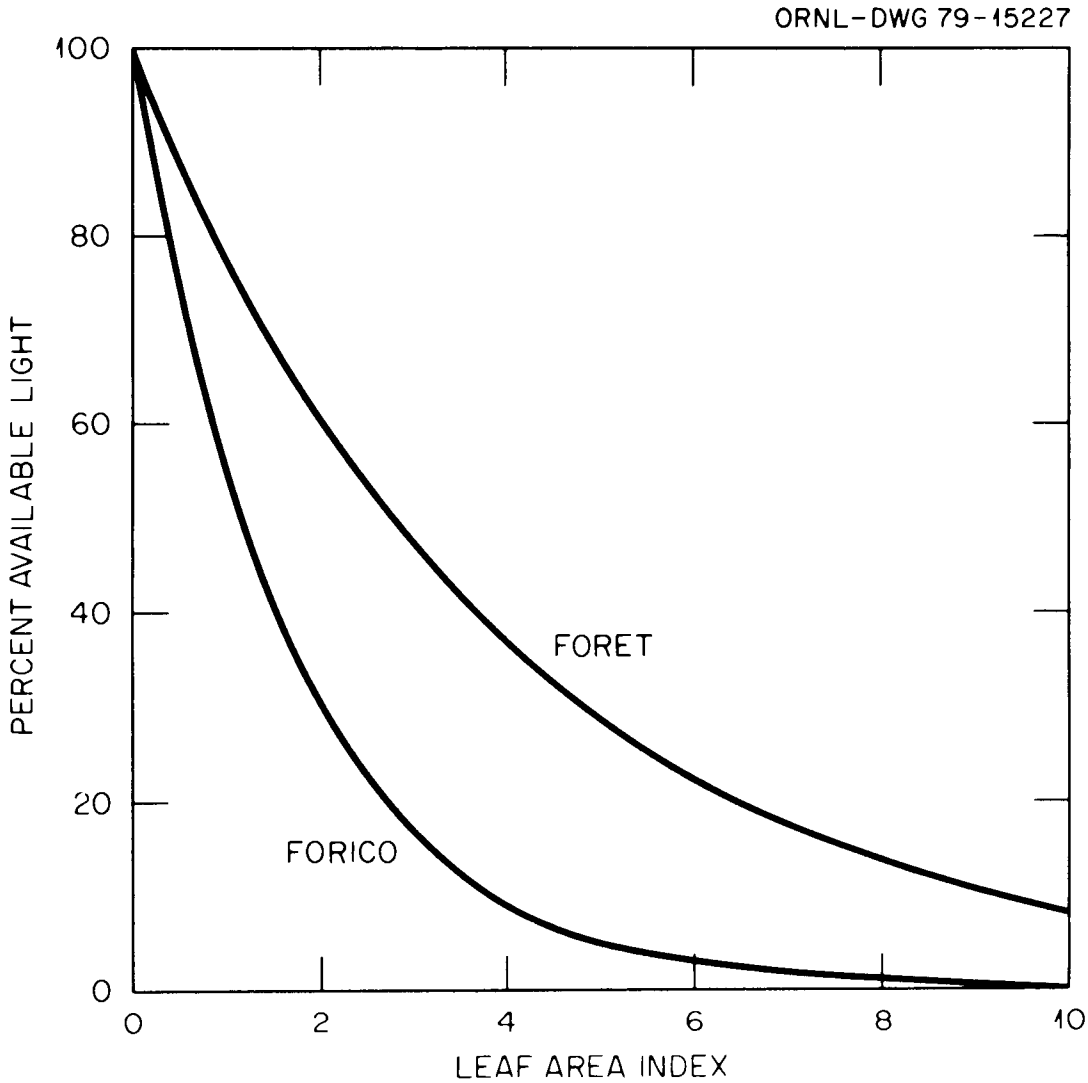

Fig. 4. Percent available light as a function of leaf area (m^2 leaf area/m^2 land area) as treated in the FORICO and the FORET models (Shugart and West 1977).

where TOL = 1 represents shade-tolerant species and TOL = 3 signifies shade-intolerant species. The coefficients 47.22 and 1.24 were derived from photosynthesis curves of tolerant and intolerant species, respectively (Lugo 1970). The constants 0.004 and 0.03, also taken from Lugo (1970), represent light compensation points at which energy expended in respiration equals that stored from photosynthesis, thus resulting in zero growth. The shade effect on shade-intermediate species (TOL = 2) was calculated by averaging the shade-tolerant and shade-intolerant functions. The shade-tolerance class (TOL) for each of the model species was taken from Smith (1970) (Table 1). Figures 5 and 6 compare, for shade-tolerant and shade-intolerant species, respectively, differences in photosynthetic efficiency between evergreen tropical and deciduous temperate species as simulated in the FORICO and FORET models.

As stand biomass increases, competition for space and nutrients limits potential growth, scaled to 1.0 for open stands, according to the function:

$$S(BAR) = 1 - BAR/SOILQ \quad . \tag{11}$$

BAR represents the total biomass on the stand, while SOILQ signifies the maximum biomass recorded for a forest. Total biomass, BAR, is calculated by summing the biomass for all trees on the stand from a biomass-diameter regression (Fig. 7):

$$BAR = a\ D^b \quad , \tag{12}$$

where BAR is the biomass of a tree of diameter D, and a and b are constants with values of 0.1568 and 2.2337, respectively, derived from

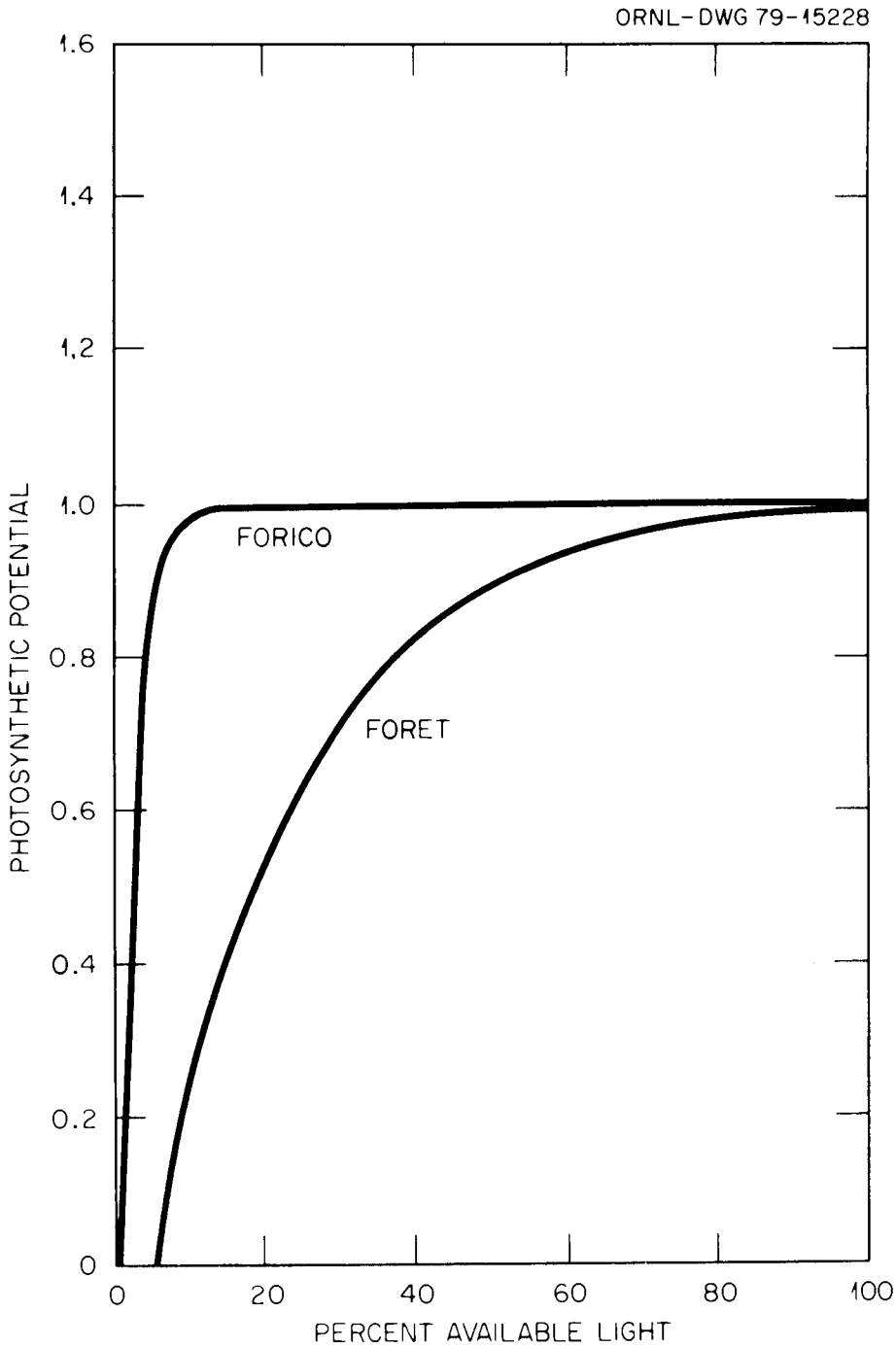

Fig. 5. Photosynthetic potential as a function of percent available light for shade-tolerant species as treated in the FORICO and FORET models.

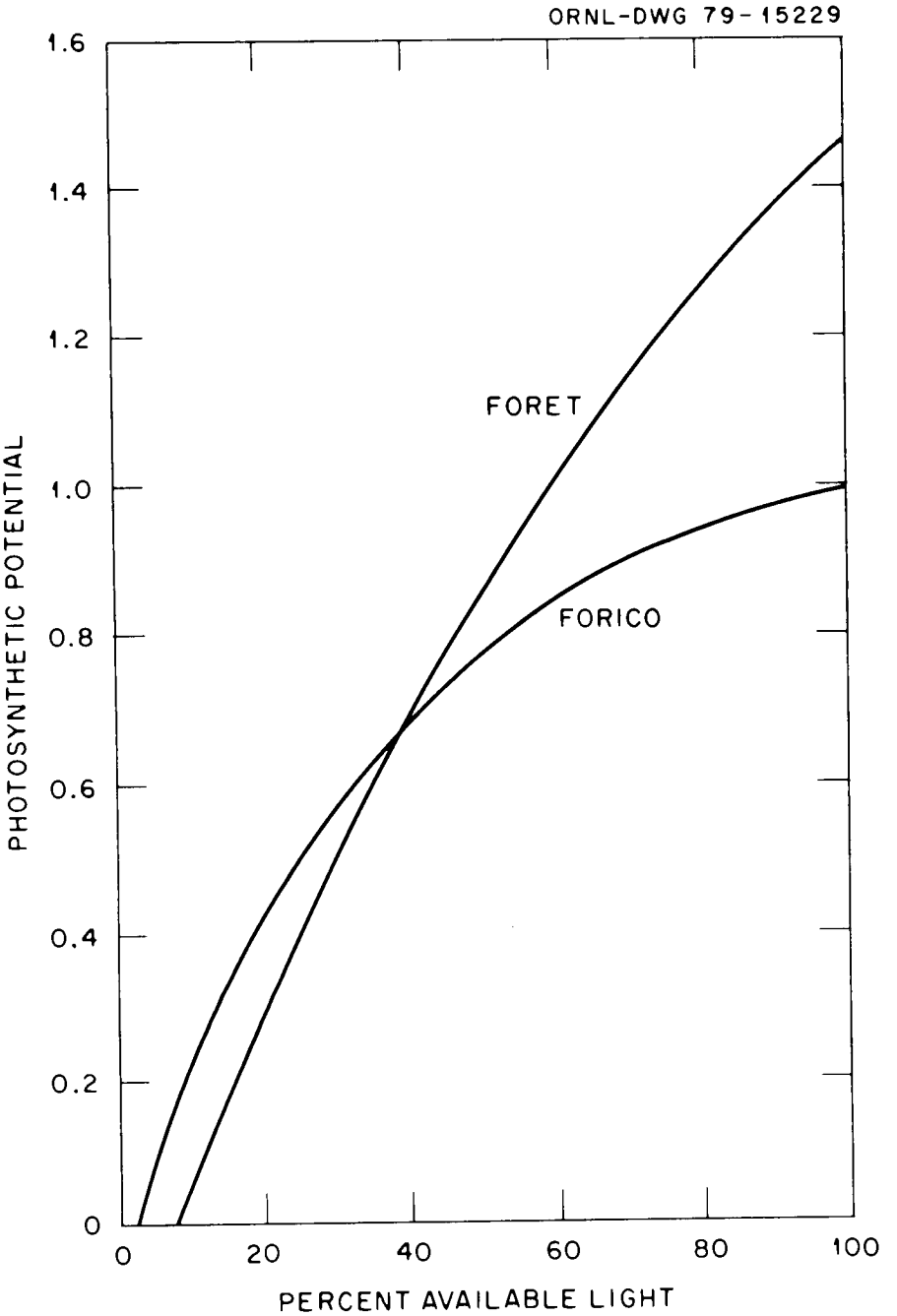

Fig. 6. Photosynthetic potential as a function of percent available light for shade-intolerant species as treated in the FORICO and FORET models.

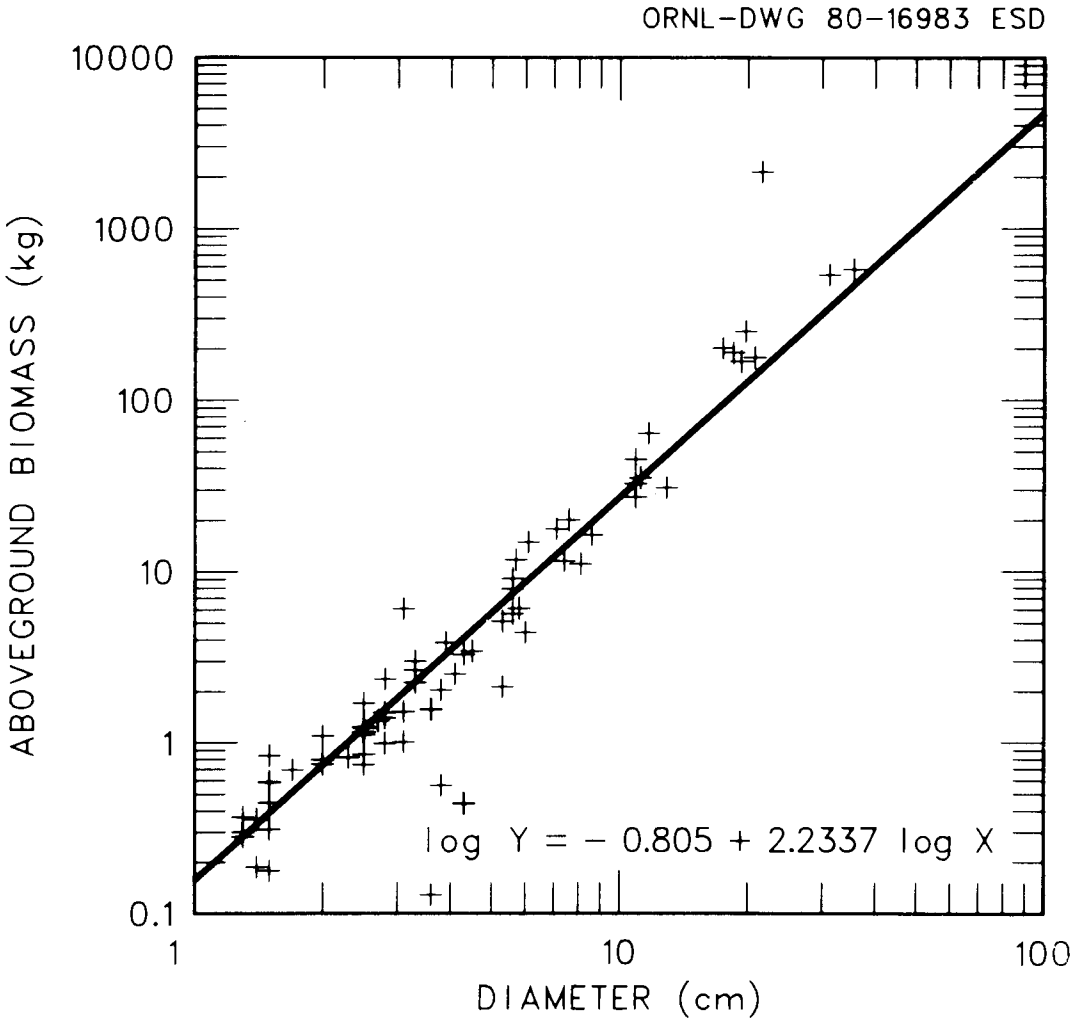

Fig. 7. Regression of aboveground biomass with tree diameter.

biomass data in the appendix of Ovington and Olson (1970). An estimated SOILQ of 400 m^2/ha was obtained from data of virgin stands in the lower montane rain forest on the nearby island of Dominica (Sorianno-Ressy et al. 1970).

Subroutine KILL

The KILL subroutine (Fig. 2) eliminates trees from the simulated stand as a stochastic function of ageand growth-related deaths. Each tree is assumed to have an intrinsic mortality rate such that under normal conditions only 1% of all seedlings in a cohort ever live to reach their life expectancy. The probability of a tree dying in any one year can then be expressed as:

$$p_m = 1 - \exp(-4.605/AGEMX) \quad , \tag{13}$$

where p_m is the intrinsic probability of mortality, and AGEMX (Table 1) is the maximum age for the species. Maximum age figures for each species were extrapolated by using the species growth parameter, G, and maximum tree dimensions, Dmax and Hmax, in a supplemental program adapted from Botkin et al. (1972) (see Appendix A). Suppressed individuals that fail to maintain a growth rate greater than 1 mm/year are subjected to an additional probability of 0.368 of dying. This additional mortality factor has the effect of allowing only 1% of a suppressed cohort to survive 10 years.

Subroutine HURCAN

This subroutine (Fig. 2) stochastically mimics cyclone storm effects common to forests in the West Indies. Wadsworth and Englerth

(1959) reported from historical records that a hurricane passes over Puerto Rico about once every nine years. Thus, the model has a return frequency probability of 0.111 that a hurricane will occur in any one year of simulation. The impact of these tropical storms is simulated as a variable probability of stand damage where 0 to 10% of the total stand density can be affected.

Utility Subroutines

Support subroutines which facilitate model operation from the programming aspect, rather than from a biological end, are termed utility subroutines. Subroutine INPUT (Fig. 2) calls in the species list and model parameters in Table 1 and stores this information in preassigned variable arrays. The INIT subroutine (Fig. 2) initializes stand conditions and various storage and counting arrays. The OUTPUT subroutine (Fig. 2) holds the model results after each year to average stand and species data at the end of the simulation. Biomass, stem density, leaf area, and individual tree diameters by species and for the entire stand are currently generated for output (see Appendix B).

MODEL EXECUTION

The FORICO model has been executed interactively on a PDP-10 computer as well as in batch mode on an IBM system. The program is written in FORTAN IV and is readily portable. Model execution is started by setting the number of plots, KLAST, and desired years, NYEAR, of simulation. Initial stand condition represents a newly formed gap clearing with no standing trees, although actual forest data can be entered. The FORICO model considers 36 tree species and

9 species-specific parameters, but it can be modified to handle any number of species and model parameters. A listing of the FORICO program is given in Appendix C.

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APPENDIX A

SUPPLEMENTAL PROGRAM FOR CALCULATING SPECIES AGE MAXIMUM

```
C......
C...    SUPPLEMENTAL PROGRAM FOR CALCULATING SPECIES AGE MAXIMUM
C.......
        WRITE(5,10010)
10010   FORMAT(1H0,'MAXIMUM AGE CALCULATOR')
20      WRITE(5,10020)
10020   FORMAT(1H0,'INPUT HMAX, DMAX, AND G')
        ACCEPT*,HMAX,DMAX,G
        IF(HMAX.EQ.0.0) GO TO 10
        WRITE(5,10030)HMAX,DMAX,G
10030   FORMAT(1H0,'HMAX =',E16.8,2X,'DMAX =',E16.8,2X,'G =',E16.3)
        A=1.-137./HMAX
        B2=2.*(HMAX-137.)/DMAX
        B3=(HMAX-137.)/DMAX**2
        SQT=SQRT(A**2+4.*A)
        AGEMX=(4.*HMAX)/G*(ALOG(2.*(2.*DMAX-1.))+(A/2.)*ALOG
     1  ((9./4.+A/2.)/(4.*DMAX**2+2.*A*DMAX-A))-((A+A**2/2)/
     2  SQT)*ALOG(((3.+A-SQT)/(3.+A+SQT))*((4.*DMAX+A+SQT)/(4.*DMAX
     3  +A-SQT))))
        WRITE(5,10040)B2,B3,AGEMX
10040   FORMAT(1X,'B2    =',E16.8,2X,'B3    =',E16.8,2X,'AGEMX =',E16.8)
        GO TO 20
10      STOP
        END
```

APPENDIX B

SAMPLE OUTPUT OF FORICO MODEL

```
C.....
C.....LOWER MONTANE RAIN FOREST SUCCESSION MODEL
C.....
      COMMON/FOREST/NTREES(100),DBH(700),IAGE(700),
     1SUMLA(700),NCODE(700),NOGRO(700)
      COMMON/PARAM/AAA(100,6),DMAX(100),HMAX(100),B3(100),B2(100)
     1ITOL(100),AGEMX(100),G(100),SMIN(100),SMAX(100)
      COMMON/CONST/NSPEC,SOILQ
      COMMON/LIGHT/SUN
      COMMON/RAND/YFL
      COMMON/COUNT/NTOT,NYEAR
      COMMON/YYEAR/NYR
      COMMON/PARENT/SEEDS(100)
      COMMON/PASSX/A(1001,39)
      COMMON/SEED/USEED(13)
      INTEGER USEED
C.....REFERENCE FOR RANDOM NUMBER GENERATOR - DESIGN AND USE OF COMPUTER
C.....SIMULATION MODELS - EMOLTOFF AND SISSON - THE MACMILLAN COMPANY
C.....
C.....USEED(1) - KILL  TEST MAXIMUM AGE FOR EACH TREE
C.....USEED(2) - KILL- TEST GT .368 FOR TREE TO DIE
C.....
C.....
C.....INITIALIZE SEED FOR RANDOM NUMBER GENERATOR
C.....
      USEED(1) = 68562
      USEED(2) = 24700
      USEED(3) = 51061
      USEED(4) = 89747
      USEED(5) = 57166
      USEED(6) = 95083
      USEED(7) = 22567
      USEED(8) = 14707
      USEED(9) = 33295
      USEED(10) = 70014
      USEED(11) = 59693
      USEED(12) = 50816
      USEED(13) = 41575
      CALL INPUT
      IPLOT = 0
      KLAST = 12
      NYEAR = 500
      NYR1 = NYEAR+1
      KTIMES = 1
      N3 = NSPEC+3
      DO 10 IVA = 1,NYR1
      DO 10 IVS = 1,N3
      A(IVA,IVS) = 0.
   10 CONTINUE
C.....
C.....SOILQ - THE MAXIMUM BIOMASS RECORDED FOR FORESTS IN THE AREA
C.....
      SOILQ = 13320.0
C.....
```

Appendix B. (continued)

```
C.....
C.....
C.....NSPEC - NUMBER OF SPECIES FOR SIMULATION
C.....
C       WRITE(30,2400)
 2400 FORMAT('  HURCAN= YES , DAM = 0.1, SLAR= 1.0, MPLANT= 6,
     1SOILQ= 13320.0 , SEEDIN = .5 , LITEXT= .60 ')
   20 CONTINUE
      CALL RANDOM(USEED(5))
      NYR =    NYEAR
      KYR = 0
      CALL PLOTIN(KYR,IPLOT)
C       WRITE(30,2010) IPLOT
 2010 FORMAT(/,'  PLOT NUMBER  ',I4)
      CALL OUTPUT(KYR,IPLOT)
      DO 75 KK=1,KTIMES
      DO 50 I=1,NYEAR
      KYR = I
      CALL KILL(KYR)
      CALL HURCAN(KYR)
      CALL BIRTH(KYR)
      CALL GROW(KYR,IPLOT)
      CALL RANK(KYR,IPLOT)
      CALL DBHDIS(KYR,IPLOT)
      CALL OUTPUT(KYR,IPLOT)
   50 CONTINUE
   75 CONTINUE
      IF(IPLOT .NE. KLAST) GO TO 20
      ZNYR = KLAST
      DO 100 IV1 = 1,NYR1
      TIMEX = IV1-1
C       WRITE(30,2000) TIMEX
C       WRITE(4,2020)TIMEX
 2020 FORMAT(2E10.3)
      DO 90 IV2 = 1,N3
      A(IV1,IV2) = A(IV1,IV2)/ZNYR
 2000 FORMAT(' ',2E10.3)
C       WRITE(4,2020)A(IV1,IV2)
   90 CONTINUE
  100 CONTINUE
      STOP
      END
```

Appendix B. (continued)

```
      SUBROUTINE INPUT
      COMMON/PARAM/AAA(100,6),DMAX(100),HMAX(100),B3(100),B2(100),
     1ITOL(100),AGEMX(100),G(100),SMIN(100),SMAX(100)
      COMMON/CONST/NSPEC,SOILQ
      DIMENSION NSELCT(100)
      READ(5,1000) NSPEC,(NSELCT(I),I=1,NSPEC)
 1000 FORMAT(40I2)
      J = 1
      DO 100 K=1,100
      READ(5,1010) (AAA(J,I),I=1,6),DMAX(J),HMAX(J),B3(J),B2(J),ITOL(J),
     1AGEMX(J),G(J),SMIN(J),SMAX(J),NUMBER
 1010 FORMAT(6A4,F5.0,F5.0,F5.4,F5.2,I1,F4.0,2X,F5.2,10X,F4.0,1X,F4.0,
     1I5)
      IF(NSELCT(J) .NE. NUMBER) GO TO 100
      WRITE(6,2000) (AAA(J,I),I=1,6),DMAX(J),HMAX(J),B3(J),B2(J),
     1ITOL(J),AGEMX(J),G(J),SMIN(J),SMAX(J),NUMBER
 2000 FORMAT(' ',6A4,1X,F5.0,1X,F5.0,F6.4,1X,F6.2,1X,I1,1X,F4.0,1X,
     11X,1X,F6.2,1X,F4.2,1X,F4.2,1X,I5)
      IF(NUMBER .EQ. NSELCT(NSPEC)) GO TO 150
      J = J+1
  100 CONTINUE
  150 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PLOTIN(KYR,IPLOT)
      COMMON/FOREST/NTREES(100),DBH(700),IAGE(700),
     1SUMLA(700),NCODE(700),NOGRO(700)
      COMMON/CONST/NSPEC,SOILQ
      COMMON/COUNT/NTOT,NYEAR
      COMMON/PARENT/SEEDS(100)
C.....
C.....INITIALIZE VARIABLES TO START SIMULATION ON BARE PLOT
C.....NTREES CONTAINS NUMBER OF TREES FOR EACH SPECIES
C.....DBH CONTAINS DIAMETER AT BREAST HEIGHT FOR EACH TREE
C.....NOGRO IS USED TO FLAG THE TREES THAT DON'T GROW
C.....IAGE CONTAINS THE AGE FOR EACH TREE
C.....
      IPLOT = IPLOT+1
      NTOT = 0
      DO 10 I=1,NSPEC
      SEEDS(I) = 0
      IAGE(I) = 0
      NTREES(I) = 0
      NOGRO(I) = 0
   10 CONTINUE
      NSPE1 = NSPEC + 1
      DO 15 I=NSPE1,700
      IAGE(I) = 0
      NOGRO(I) = 0
   15 CONTINUE
      RETURN
      END
      SUBROUTINE RANDOM(NSEED)
      COMMON/RAND/YFL
      YFL = RANDU(NSEED)
      RETURN
      END
```

Appendix B. (continued)

```
      SUBROUTINE HURCAN(KYR)
      COMMON/FOREST/NTREES(100),DBH(700),IAGE(700),
     1SUMLA(700),NCODE(700),NOGRO(700)
      COMMON/PARAM/AAA(100,6),DMAX(100),HMAX(100),B3(100),B2(100),
     1ITOL(100),AGEMX(100),G(100),SMIN(100),SMAX(100)
      COMMON/LIGHT/SUN
      COMMON/RAND/YFL
      COMMON/COUNT/NTOT
      COMMON/SEED/USEED(9)
      INTEGER USEED
C.....
      SLAR = 0.0
      IF (NTOT .EQ. 0) RETURN
      CALL RANDOM(USEED(2))
      IF (YFL .GT. 0.111) RETURN
      CALL RANDOM(USEED(3))
      DAM = YFL * 0.2
      K = 0
      DO 10 I=1,NTOT
      J = NCODE(I)
      CALL RANDOM(USEED(4))
      IF (YFL .GT. DAM) GO TO 10
      K = K + 1
      DBH(I) = -1.0
      NTREES(J) = NTREES(J) - 1
 10   CONTINUE
      IF (K .NE. NTOT) GO TO 15
      SUN = 1.0
      NTOT = 0
      DO 14 I=1,700
      IAGE(I) = 0
      NOGRO(I) = 0
14    CONTINUE
      WRITE(6,2002)
 2002 FORMAT(' ','ALL TREES HAVE BEEN ELIMINATED')
      RETURN
  15  CONTINUE
C.......
C...... REWRITE DIAMETERS AND AGES TO ELIMINATE DEAD TREES
C.....
      J = 0
      DO 20 I=1,NTOT
      IF (DBH(I) .LT. 0.) GO TO 20
      J = J + 1
      DBH(J) = DBH(I)
      IAGE(J) = IAGE(I)
      NCODE(J) = NCODE(I)
 20   CONTINUE
      NTOT = J
      DO 30 I=1,NTOT
  30  SLAR = SLAR + 1.485544E-3*DBH(I)**1.548
      SUN = 1.0*EXP(-SLAR*.60)
C      WRITE(6,2001)DAM,SLAR,SUN
 2001 FORMAT(' ','HURRICANE','DAM=',F10.7,5X,'SLAR=',
     1F7.4,5X,'SUN=',F5.3)
      RETURN
      END
```

Appendix B. (continued)

```
      SUBROUTINE KILL(KYR)
      COMMON/FOREST/NTREES(100),DBH(700),IAGE(700),
     1SUMLA(700),NCODE(700),NOGRO(700)
      COMMON/PARAM/AAA(100,6),DMAX(100),HMAX(100),B3(100),B2(100),
     1ITOL(100),AGEMX(100),G(100),SMIN(100),SMAX(100)
      COMMON/CONST/NSPEC,SOILQ
      COMMON/RAND/YFL
      COMMON/COUNT/NTOT,NYEAR
      COMMON/PARENT/SEEDS(100)
      COMMON/SEED/USEED(9)
      INTEGER USEED
C.....
      IF(NTOT .EQ. 0) RETURN
      NG = 1
      DO 100 K=1,NTOT
      I = NCODE(K)
      CALL RANDOM(USEED(5))
      IF(YFL .LE. (4.605/AGEMX(I))) GO TO 50
C.....
C.....CHECK TO SEE IF THERE WAS ANY GROWTH FOR TREE
C.....
      IF(NOGRO(NG) .NE. K) GO TO 100
      NG = NG+1
      CALL RANDOM(USEED(6))
      PROB=0.368
      IF (I .EQ. 14) PROB=0.0
      IF(YFL .GT. PROB) GO TO 100
   50 CONTINUE
      NTREES(I) = NTREES(I)-1
      DBH(K) = -1.0
  100 CONTINUE
C.....REWRITE DIAMETERS AND AGES TO ELIMINATE DEAD TREES
C.....
      K = 0
      DO 200 I=1,NTOT
      IF(DBH(I) .LT. 0.) GO TO 200
      K = K+1
      DBH(K) = DBH(I)
      IAGE(K) = IAGE(I)
      NCODE(K) = NCODE(I)
  200 CONTINUE
      NTOT = K
      RETURN
      END
```

Appendix B. (continued)

```
      SUBROUTINE GROW(KYR,IPLOT)
      COMMON/FOREST/NTREES(100),DBH(700),IAGE(700),
     1SUMLA(700),NCODE(700),NOGRO(700)
      COMMON/PARAM/AAA(100,6),DMAX(100),HMAX(100),B3(100),B2(100),
     1ITOL(100),AGEMX(100),G(100),SMIN(100),SMAX(100)
      COMMON/CONST/NSPEC,SOILQ
      COMMON/LIGHT/SUN
      COMMON/RAND/YFL
      COMMON/COUNT/NTOT,NYEAR
      COMMON/PARENT/SEEDS(100)
C.....
C.....EACH TREE IS REQUIRED TO ADD A 1.0 MM GROWTH RING EACH YEAR
C.....
      IF (NTOT .EQ. 0) RETURN
      TINC = .1
      PHI = 1.
      SUN = 1.0
      DO 5 I=1,NSPEC
      SEEDS(I) = 0
    5 CONTINUE
C.....
C.....CALCULATE TOTAL NUMBER OF TREES
C.....
C.....SUM LEAF AREA OF ALL TREES THAT ARE OF APPROXIMATELY
C.....THE SAME HEIGHT
C.....
      DO 10 I=1,700
      NOGRO(I) = 0
   10 SUMLA(I) = 0.
      SBIO = 0.
      DO 15 K=1,NTOT
      I = NCODE(K)
C.....
C.....CALCULATE STAND BIOMASS
C.....
      SBIO = SBIO+0.156855*DBH(K)**2.2337
C.....
C.....HEIGHT PROFILE IS CALCULATED IN .1 METER UNITS
C.....
      IHT = (B2(I)        *DBH(K)-B3(I)        *DBH(K)**2)/10.+1.
      IF(IHT .GT. 700) GO TO 100
      SUMLA(IHT) = SUMLA(IHT)+1.485544E-3*DBH(K)**1.548
      IF (KYR .NE. 15) GO TO 15
      HTREE = IHT / 10.
C      WRITE(25,2000)I,DBH(K),HTREE
 2000 FORMAT(I2,F5.1,',',F4.1)
   15 CONTINUE
      DO 25 J=1,699
      J1 = 700-J
      SUMLA(J1) = SUMLA(J1)+SUMLA(J1+1)
   25 CONTINUE
C.....
C.....CALCULATE AMOUNT OF GROWTH FOR EACH TREE
```

Appendix B. (continued)

```
C.....
C.....CALCULATE AMOUNT OF GROWTH FOR EACH TREE
C.....
      NG = 1
      DO 50 J=1,NTOT
      I = NCODE(J)
      HT = B2(I)        *DBH(J)-B3(I)        *DBH(J)**2
      IHT = HT/10.+2.
      SLAR = SUMLA(IHT)
      AL = PHI*EXP(-SLAR*.60)
      IF (AL .GE. SUN) GO TO 35
      SUN = AL
   35 CONTINUE
      GR = (137.+.25*B2(I)        **2/B3(I)        )*(0.5*B2(I)/B3(I))
      DNC = G(I)        *DBH(J)*(1.0-(137.*DBH(J)+B2(I)        *DBH(J)**2
     1-B3(I)        *DBH(J)**3)/GR)/(274.+3.0*B2(I)        *DBH(J)-4.0*
     2B3(I)        *DBH(J)**2)*(1.0-SBIO/SOILQ)
      DINC = 1.072*(1.-EXP(-2.698*(AL-.02)))*DNC
      DIAC = DINC
      IF (ITOL(I) .LE. 2) DINC = (1.0-EXP(-47.22*(AL-.004)))*DNC
      IF (ITOL(I) .EQ. 2) DINC = (DIAC + DINC) / 2.
C.....
C.....CHECK INCREMENT LESS THAN 1.0 MM REQUIRED GROWTH
C.....
      IF(DINC .GT. TINC) GO TO 28
      NOGRO(NG) = J
      NG = NG+1
28    DBH(J) = DBH(J) + DINC
      IF (DBH(J) .GT. 0.2*DMAX(I)) SEEDS(I) = 1
   50 CONTINUE
      RETURN
  100 WRITE(30,9000)
 9000 FORMAT('1 IHT EXCEEDED 700')
      STOP
      END
```

Appendix B. (continued)

```
      SUBROUTINE BIRTH(NYR)
      COMMON/FOREST/NTREES(100),DBH(700),IAGE(700),
     1SUMLA(700),NCODE(700),NOGRO(700)
      COMMON/PARAM/AAA(100,6),DMAX(100),HMAX(100),B3(100),B2(100),
     1ITOL(100),AGEMX(100),G(100),SMIN(100),SMAX(100)
      COMMON/CONST/NSPEC,SOILQ
      COMMON/LIGHT/SUN
      COMMON/RAND/YFL
      COMMON/COUNT/NTOT,NYEAR
      COMMON/PARENT/SEEDS(100)
      COMMON/SEED/USEED(9)
      INTEGER USEED
C.....
C.....SAPLINGS ENTER THE PLOT AT AVERAGE SIZE OF 1.27 CM DBH
      SIZE = 1.27
      SLAR = 0.0
C.....
      IF (NTOT .NE. 0) GO TO 20
      SUN = 1.0
      GO TO 25
C......
   20 DO 24 J=1,NTOT
   24 SLAR = SLAR+1.485544E-3*DBH(J)**1.548
      SUN = 1.0*EXP(-SLAR*.60)
   25 CONTINUE
C.....
      DO 65 I=1,NSPEC
      IF (SUN .LT. SMIN(I) .OR. SUN .GT. SMAX(I)) GO TO 65
      CALL RANDOM(USEED(7))
      PROB = 1
      IF (SEEDS(I) .NE. 0) PROB=1.0
      IF (YFL .GT. .5*PROB) GO TO 65
      CALL RANDOM(USEED(9))
      MPLANT = 6*YFL
      DO 45 J=1,MPLANT
      NTOT = NTOT+1
      IF(NTOT .GT. 700) CALL ERR
      IAGE(NTOT) = 0
      NCODE(NTOT) = I
C.....
C.....CALCULATE DBH FOR SEEDLINGS
C.....
      CALL RANDOM(USEED(9))
      DBH(NTOT) = SIZE+.3*(1.0-YFL)**3
      NTREES(I) = NTREES(I)+1
   45 CONTINUE
   65 CONTINUE
      IF (NTOT .EQ. 0) GO TO 25
      IF(SLAR .LT. 2.5) GO TO 20
C.....
C.....INCREMENT AGES
C.....
      DO 75 I=1,NTOT
      IAGE(I) = IAGE(I)+1
   75 CONTINUE
      RETURN
      END
```

Appendix B. (continued)

```
      SUBROUTINE OUTPUT(KYR,IPLOT)
      COMMON/FOREST/NTREES(100),DBH(700),IAGE(700),
     1SUMLA(700),NCODE(700),NOGRO(700)
      COMMON/PARAM/AAA(100,6),DMAX(100),HMAX(100),B3(100),B2(100),
     1ITOL(100),AGEMX(100),G(100),SMIN(100),SMAX(100)
      COMMON/PASSX/A(1001,39)
      COMMON/COUNT/NTOT,NYEAR
      COMMON/CONST/NSPEC,SOILQ
      DIMENSION BAR(100)
      IF (NTOT .EQ. 0) RETURN
      KYR1 = KYR+1
      AREA=0.0
      TBAR=0.0
      TOBAR=0.0
      DO 70 I=1,NSPEC
   70 BAR(I) = 0.
      DO 75 J=1,NTOT
      I = NCODE(J)
      BAR(I) = BAR(I)+0.156855*DBH(J)**2.2337
      AREA=AREA+1.485544E-3*DBH(J)**1.548
   75 CONTINUE
      DO 80 I=1,NSPEC
   80 TBAR = TBAR+BAR(I)
      TBAR=TBAR*.03
      DO 90 IV1=1,NSPEC
   90 BAR(IV1) = BAR(IV1) * .03
      DO 100 IV1 = 1,NSPEC
      A(KYR1,IV1) = A(KYR1,IV1) + BAR(IV1)
  100 CONTINUE
      ATOT=NTOT
      N1 = NSPEC+1
      N2 = N1+1
      N3 = N2+1
      A(KYR1,N1)=A(KYR1,N1)+TBAR
      A(KYR1,N2)=A(KYR1,N2)+ATOT
      A(KYR1,N3)=A(KYR1,N3)+AREA
C     CALL SORT(NCODE,DBH,NTOT)
C.......
C.............SORT AND WRITE SPP.,NAME,NUMBER,BIOMASS,DBH,ETC.
C......
      RETURN
      END
```

APPENDIX C

LISTING OF FORICO MODEL

```
YEAR  SPECIES     STEMS                NAME                    BIOMASS
  10

        1         (  8)        ALCHORNEA LATIFOLIA             .447E+00

      DBH  3.6   2.2   2.2   2.8   2.7   2.8   3.8   3.5

        2         (  1)        ALCHORNEOPSIS PORTORICEN        .269E-01

      DBH  2.2

        3         (  4)        BUCHENAVIA CAPITATA             .151E+00

      DBH  3.3   2.1   2.3   2.2

        4         ( 18)        BYRSONIMA CORIACEA              .236E+01

      DBH  6.8   3.4   4.8   4.5   7.2   1.9   1.7   1.7
           1.8   6.6   2.7   3.2   4.9   4.5   3.4   5.1
           5.0   3.2

        5         ( 17)        CASEARIA ARBOREA                .133E+01

      DBH  2.3   4.5   2.4   3.6   4.0   4.4   4.0   2.3
           4.0   4.7   3.3   4.8   3.2   1.6   2.6   1.4
           3.5

        7         ( 24)        CECROPIA PELTATA                .688E+01

      DBH  4.1   3.4  10.2   2.0   2.3   8.0  10.3  10.1
           4.3   4.4  10.7   2.0   2.0  10.0   4.3   3.4
           1.9   2.9   5.4   2.2   9.9   3.0   2.8   5.3

        8         ( 20)        CORDIA BORINQUENSIS             .171E+01

      DBH  2.0   2.2   5.2   2.6   5.1   2.3   4.2   2.3
           2.6   4.1   3.5   5.1   3.8   1.9   2.6   5.3
           3.9   2.2   2.3   5.1

        9         (  8)        CYATHEA ARBOREA                 .204E+01

      DBH  2.2   2.1   6.6   2.5   5.4   8.4   8.5   6.6

       11         ( 24)        DIDYMOPANAX MOROTOTONI          .109E+02

      DBH  6.2   3.3   3.3   9.5   3.6   2.7   6.0   9.6
           2.9   7.5   5.2  10.0   9.6   6.6   9.5   8.0
           3.3   9.5   9.5  10.0   9.5   8.0  10.3   8.0

       14         (  9)        EUTERPE GLOBOSA                 .447E+01

      DBH  9.3  10.5  10.5   5.5   5.5   8.1   6.9   6.9
           6.9
```

Appendix C. (continued)

```
  15        ( 1)        GUAREA RAMIFLORA          .252E-01

DBH  2.1

  18        ( 4)        HOMALIUM RACEMOSUM        .920E-01

DBH  2.3   2.0   1.9   1.9

  19        ( 3)        INGA LAURINA              .106E+00

DBH  2.4   2.5   2.5

  20        ( 8)        INGA VERA                 .517E+00

DBH  2.5   3.8   2.3   3.8   4.0   2.6   3.7   2.3

  21        ( 1)        LAETIA PROCERA            .143E-01

DBH  1.6

  22        ( 8)        LINOCIERA DOMINGENSIS     .357E+00

DBH  3.1   2.2   2.2   3.2   2.2   3.0   2.5   3.2

  25        ( 3)        MICONIA PRASINA           .651E-01

DBH  1.9   2.1   1.9

  26        ( 7)        MICONIA TETRANDRA         .345E+00

DBH  2.5   2.3   3.8   2.3   2.4   3.8   2.3

  27        ( 2)        OCOTEA LEUCOXYLON         .675E-01

DBH  2.4   2.4

  29        ( 4)        ORMOSIA KRUGII            .155E+00

DBH  2.5   2.5   2.6   2.6

  30        ( 29)       PALICOUREA RIPARIA        .195E+01

DBH  4.4   4.3   3.2   4.5   4.3   4.6   4.3   4.6
     4.4   4.5   3.5   2.9   1.6   2.0   2.0   2.0
     2.3   4.6   4.3   2.0   1.8   1.9   2.1   1.7
     1.5   1.7   3.2   1.7   1.6

  31        ( 12)       PSYCHOTRIA BERTERIANA     .989E+00

DBH  2.3   5.2   4.6   5.1   2.2   1.6   4.3   1.8
     3.0   5.0   2.1   1.6

  32        ( 5)        SAPIUM LAUROCERASUS       .832E-01

DBH  1.6   2.2   1.6   1.6   1.6

  34        ( 3)        TABEBUIA HETEROPHYLLA     .523E-01

DBH  1.8   1.9   1.7

223-- STEMS        0.351E+02MT/HA.    LAI =  3.218
```

Appendix C. (continued)

YEAR 20	SPECIES	STEMS	NAME	BIOMASS
	1	(8)	ALCHORNEA LATIFOLIA	.383E+01
	DBH 8.4 8.6 9.6 9.8 11.4 2.7 2.5 2.8			
	2	(3)	ALCHORNEOPSIS PORTORICEN	.668E+00
	DBH 8.7 2.5 2.4			
	3	(3)	BUCHENAVIA CAPITATA	.194E+01
	DBH 10.4 8.3 8.4			
	4	(11)	BYRSONIMA CORIACEA	.206E+01
	DBH 3.5 3.6 2.6 2.7 5.3 9.4 9.8 1.4 3.8 2.6 1.4			
	5	(10)	CASEARIA ARBOREA	.111E+01
	DBH 5.4 2.5 1.7 7.5 1.7 3.9 2.1 6.0 1.8 1.7			
	6	(2)	CASEARIA SYLVESTRIS	.309E-01
	DBH 1.7 1.7			
	7	(10)	CECROPIA PELTATA	.920E+01
	DBH 5.0 3.3 3.3 10.7 20.2 16.8 5.2 10.8 4.8 5.2			
	8	(16)	CORDIA BORINQUENSIS	.431E+01
	DBH 6.1 7.9 8.7 3.9 8.7 2.1 8.9 7.7 8.8 3.3 3.9 3.3 3.3 3.6 2.7 5.2			
	9	(9)	CYATHEA ARBOREA	.139E+01
	DBH 1.7 2.2 1.7 1.5 2.2 1.5 1.5 2.3 12.1			
	11	(9)	DIDYMOPANAX MOROTOTONI	.177E+02
	DBH 19.0 3.4 8.0 19.7 2.1 18.8 19.2 18.8 2.8			
	14	(5)	EUTERPE GLOBOSA	.768E+00
	DBH 3.4 6.3 6.3 3.1 3.0			
	15	(1)	GUAREA RAMIFLORA	.213E-01
	DBH 2.0			
	18	(11)	HOMALIUM RACEMOSUM	.101E+01
	DBH 2.1 2.3 2.0 2.0 2.1 6.0 6.5 2.1 5.8 2.3 2.1			
	19	(9)	INGA LAURINA	.909E+00
	DBH 9.0 2.2 2.8 2.8 2.2 2.2 2.2 2.8 2.2			

Appendix C. (continued)

```
  20        ( 4)        INGA VERA                    .439E+01

DBH 10.5  12.5  12.8   9.8

  21        ( 3)        LAETIA PROCERA               .334E-01

DBH  1.5   1.5   1.5

  22        ( 7)        LINOCIERA DOMINGENSIS        .383E+01

DBH  8.2   7.8   7.8   9.1   7.8   9.1   8.9

  25        ( 4)        MICONIA PRASINA              .864E-01

DBH  1.8   1.9   2.2   2.1

  26        ( 5)        MICONIA TETRANDRA            .183E+01

DBH  9.4   2.2  11.1   3.1   2.2

  29        ( 7)        ORMOSIA KRUGII               .158E+01

DBH  1.9   1.9   2.2   8.0   8.2   8.0   1.9

  30        ( 18)       PALICOUREA RIPARIA           .703E+00

DBH  1.9   2.1   2.0   2.0   2.2   1.7   1.9   2.0
     1.8   2.7   2.2   2.4   1.6   1.7   6.2   2.6
     1.7   2.8

  31        ( 11)       PSYCHOTRIA BERTERIANA        .257E+00

DBH  1.8   2.3   2.0   1.8   1.7   2.8   2.8   1.4
     2.0   1.7   1.4

  32        ( 5)        SAPIUM LAUROCERASUS          .340E+00

DBH  1.6   3.7   4.5   1.6   3.7

  34        ( 8)        TABEBUIA HETEROPHYLLA        .275E+00

DBH  1.8   1.5   1.7   1.8   1.6   4.0   3.6   1.7


179-- STEMS        0.583E+02MT/HA.    LAI =  3.816


YEAR  SPECIES     STEMS              NAME                 BIOMASS
 50

  2         ( 3)        ALCHORNEOPSIS PORTORICEN     .192E+01

DBH  9.4   8.8   8.8

  3         ( 5)        BUCHENAVIA CAPITATA          .580E+01

DBH 13.4  13.4   8.6  13.5   8.5

  4         ( 16)       BYRSONIMA CORIACEA           .211E+01

DBH  7.1   5.2   3.2   2.5   6.3   9.0   1.7   1.7
     1.6   2.4   2.7   4.3   4.3   3.2   2.4   3.0
```

Appendix C. (continued)

```
   5        ( 11)        CASEARIA ARBOREA            .215E+01

DBH  1.4   1.4   5.2   1.8   1.4   3.6   1.4   1.4
     6.3   1.7  13.3

   6        ( 3)         CASEARIA SYLVESTRIS         .498E+00

DBH  6.8   3.4   3.6

   7        ( 10)        CECROPIA PELTATA            .466E+00

DBH  1.6   2.3   3.7   3.7   2.1   3.4   3.7   1.6
     1.6   2.4

   8        ( 18)        CORDIA BORINQUENSIS         .270E+01

DBH  2.1   6.7   4.3   5.9   4.8   4.3   4.1   1.8
     3.2   1.6   2.9   5.9   9.7   2.8   3.2   5.9
     3.5   1.8

   9        ( 5)         CYATHEA ARBOREA             .235E+00

DBH  3.0   1.7   3.8   3.0   1.9

  10        ( 2)         DACROYDES EXCELSA           .159E+01

DBH  9.9  10.0

  11        ( 12)        DIDYMOPANAX MOROTOTONI      .193E+02

DBH  1.8   9.6   1.8   2.0   4.1   4.0  39.5   4.4
     8.7   1.9   4.0   4.0

  12        ( 2)         DRYPETES GLAUCA             .401E+00

DBH  5.4   5.3

  13        ( 2)         EUGENIA STAHLII             .416E+00

DBH  5.5   5.4

  14        ( 3)         EUTERPE GLOBOSA             .855E+00

DBH  6.2   6.2   6.4

  15        ( 2)         GUAREA RAMIFLORA            .160E+01

DBH 12.4   6.3

  18        ( 4)         HOMALIUM RACEMOSUM          .333E+01

DBH 16.7   6.0   6.0   6.2

  20        ( 2)         INGA VERA                   .104E+02

DBH 28.4  15.2

  21        ( 1)         LAETIA PROCERA              .699E+00

DBH  9.4

  22        ( 1)         LINOCIERA DOMINGENSIS       .919E+00

DBH 10.6

  24        ( 1)         MATAYBA DOMINGENSIS         .952E+00

DBH 10.8
```

Appendix C. (continued)

```
  26        ( 1)        MICONIA TETRANDRA          .467E+01

DBH 22.0

  29        ( 2)        ORMOSIA KRUGII             .486E+01

DBH 21.5   7.2

  30        ( 8)        PALICOUREA RIPARIA         .260E+00

DBH  2.9   1.4   3.5   1.7   2.0   3.0   1.7   1.7

  31        ( 12)       PSYCHOTRIA BERTERIANA      .181E+00

DBH  1.9   1.7   2.0   1.6   2.3   1.4   1.6   1.6
     1.4   1.5   1.4   1.4

  32        ( 1)        SAPIUM LAUROCERASUS        .860E+00

DBH 10.3

  33        ( 1)        SLOANEA BERTERIANA         .113E+01

DBH 11.6

  34        ( 4)        TABEBUIA HETEROPHYLLA      .802E+00

DBH  4.0   3.9   6.1   6.7

132-- STEMS        0.691E+02MT/HA.    LAI =  3.602


YEAR  SPECIES     STEMS              NAME                  BIOMASS
 100

   1        ( 3)        ALCHORNEA LATIFOLIA        .182E+01

DBH  8.8   8.7   8.9

   2        ( 1)        ALCHORNEOPSIS PORTORICEN   .100E+01

DBH 11.0

   3        ( 1)        BUCHENAVIA CAPITATA        .881E+00

DBH 10.4

   4        ( 6)        BYRSONIMA CORIACEA         .337E+01

DBH 13.5  10.6   6.2   2.1   8.3   2.6

   5        ( 14)       CASEARIA ARBOREA           .304E+00

DBH  2.4   1.5   3.3   1.4   1.7   1.4   1.4   2.7
     1.8   1.6   2.5   1.4   1.8   1.5

   6        ( 2)        CASEARIA SYLVESTRIS        .349E+00

DBH  5.0   5.1
```

Appendix C. (continued)

```
  7        ( 10)        CECROPIA PELTATA            .301E+01

DBH  2.1  12.8   1.8   4.7   3.7   1.9   2.3   2.3
     2.3  12.0

  8        ( 14)        CORDIA BORINQUENSIS         .121E+01

DBH  4.3   2.1   7.6   1.9   3.6   1.8   5.2   2.8
     1.8   2.1   2.8   3.8   2.1   2.9

  9        (  3)        CYATHEA ARBOREA             .423E-01

DBH  1.7   1.7   1.5

 10        (  1)        DACROYDES EXCELSA           .162E+00

DBH  4.9

 11        (  9)        DIDYMOPANAX MOROTOTONI      .281E+01

DBH  1.7   7.2   6.9   9.4   1.6   1.5   1.5   8.7
     9.6

 12        (  3)        DRYPETES GLAUCA             .208E+00

DBH  3.3   3.3   3.4

 14        (  5)        EUTERPE GLOBOSA             .528E+01

DBH  7.5   5.3   7.6  18.6  11.0

 15        (  1)        GUAREA RAMIFLORA            .124E+01

DBH 12.1

 16        (  1)        GUAREA TRICHILOIDES         .955E-01

DBH  3.8

 18        (  1)        HOMALIUM RACEMOSUM          .388E+00

DBH  7.2

 19        (  6)        INGA LAURINA                .595E+01

DBH  8.0   8.1   9.2  13.4  15.8   8.0

 20        (  4)        INGA VERA                   .802E+01

DBH 14.0  22.9   8.7   8.9

 21        (  5)        LAETIA PROCERA              .764E+00

DBH  5.8   3.6   5.8   3.9   4.1

 22        (  5)        LINOCIERA DOMINGENSIS       .736E+01

DBH 17.9  13.6  13.7   7.1   9.8

 23        (  3)        MANILKARA BIDENTATA         .689E+00

DBH  5.8   5.7   5.6

 25        (  1)        MICONIA PRASINA             .206E+00

DBH  5.4
```

Appendix C. (continued)

```
  26        ( 3)        MICONIA TETRANDRA          .597E+01

DBH 20.5  10.9  10.9

  28        ( 3)        OCOTEA MOSCHATA            .960E-01

DBH  2.3   2.4   2.4

  29        ( 4)        ORMOSIA KRUGII             .717E+01

DBH  9.1  13.5  21.7   7.3

  30        ( 10)       PALICOUREA RIPARIA         .717E+00

DBH  2.5   6.1   1.5   5.7   1.6   2.8   2.5   2.0
     1.4   2.6

  31        ( 8)        PSYCHOTRIA BERTERIANA      .737E+00

DBH  8.0   1.7   1.7   1.7   5.0   1.6   1.5   1.4

  32        ( 2)        SAPIUM LAUROCERASUS        .289E+00

DBH  4.4   4.8

  33        ( 1)        SLOANEA BERTERIANA         .272E+00

DBH  6.1

  34        ( 3)        TABEBUIA HETEROPHYLLA      .769E+00

DBH  8.8   3.6   3.5

133-- STEMS        0.612E+02MT/HA.    LAI =  3.736


YEAR  SPECIES     STEMS              NAME                  BIOMASS
 500

   3        ( 5)        BUCHENAVIA CAPITATA        .506E+01

DBH  9.7  10.4   5.4   6.6  17.8

   8        ( 10)       CORDIA BORINQUENSIS        .455E+00

DBH  3.2   3.1   4.9   1.4   1.3   1.5   3.0   1.4
     3.1   1.4

  10        ( 32)       DACROYDES EXCELSA          .593E+02

DBH  9.6  19.1   1.3  33.6  16.3   3.9   1.6   2.4
     4.0   3.5  32.5  17.9  21.5   2.8   3.7   1.6
     5.5  33.1   5.5   3.1  17.7   4.8   2.8   1.4
     9.7   3.1   2.6   3.8   4.7   3.2   4.8  22.5

  12        ( 14)       DRYPETES GLAUCA            .188E+01

DBH  3.3   1.6   1.3  10.0   3.2   1.3   1.8   8.8
     2.7   3.3   1.3   3.9   2.8   1.9
```

Appendix C. (continued)

```
  13          ( 14)          EUGENIA STAHLII                .611E+01

DBH 10.8    3.4    3.9    1.3    6.2   20.6    2.9    2.7
     4.9    5.6    1.7    4.1    1.5    2.8

  14          (  1)          EUTERPE GLOBOSA                .113E+00

DBH  4.2

  16          ( 31)          GUAREA TRICHILOIDES            .318E+01

DBH  2.1    2.1    3.3    2.0    3.2    4.5    1.3    2.2
    15.2    2.2    1.9    2.6    2.6    3.0    2.6    2.8
     2.2    2.2    1.8    3.3    3.1    3.6    3.3    1.7
     1.7    2.4    2.1    1.7    1.6    1.6    1.7

  17          ( 12)          HIRTELLA RUGOSA                .344E+00

DBH  2.0    1.7    3.1    2.2    1.3    2.6    1.4    1.3
     3.3    2.9    1.7    1.7

  18          (  3)          HOMALIUM RACEMOSUM             .415E+01

DBH  7.6   14.4   14.7

  19          (  5)          INGA LAURINA                   .141E+02

DBH 16.7   18.0   18.1   18.0   16.7

  20          (  2)          INGA VERA                      .261E+01

DBH 14.8    9.2

  23          ( 25)          MANILKARA BIDENTATA            .494E+02

DBH  3.5    4.2   10.8    3.5    1.8    9.9    6.4   40.2
     2.7    5.7    2.0   10.5    5.1    4.7   37.3    4.9
     1.6   25.7    3.7    5.7    2.5   21.7    4.6    7.2
     2.0

  24          ( 10)          MATAYBA DOMINGENSIS            .236E+01

DBH  4.9    6.7    7.7    7.1    6.3    6.0    4.8    6.0
     2.4    2.6

  28          ( 19)          OCOTEA MOSCHATA                .314E+00

DBH  2.1    1.4    1.5    1.8    1.4    2.2    1.7    1.7
     2.2    1.8    1.6    1.6    1.4    2.4    1.4    1.8
     1.6    1.3    2.1

  33          ( 22)          SLOANEA BERTERIANA             .141E+02

DBH  1.4    1.7    2.4    1.7    3.8   17.3    1.6    2.2
     1.6    1.6    1.4    3.3    2.4    9.4    4.9    8.2
     9.2   11.5   26.5    2.1    3.4    9.3

  35          ( 15)          TETRAGASTRIS BALSAMIFERA       .451E+01

DBH  2.9    4.7    8.5    2.1   10.8    3.7    5.9   10.0
     6.5    3.6    4.3    2.5    4.8    2.2   10.6

  36          ( 19)          TRICHILIA PALLIDA              .319E+00

DBH  1.3    1.4    1.9    1.4    2.5    1.4    2.3    1.6
     1.6    2.0    1.3    2.1    1.3    2.0    1.9    1.5
     1.6    1.6    2.1

228-- STEMS        0.197E+03MT/HA.     LAI =  7.120
```

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