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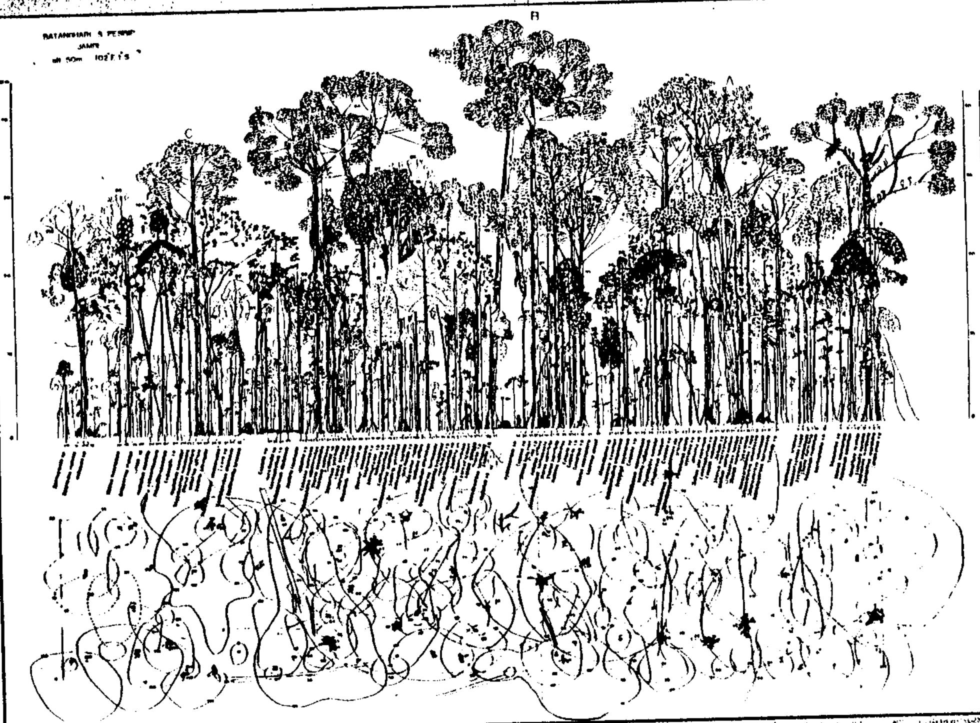
TROPICAL FOREST DYNAMICS



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A THREE DIMENSIONAL DYNAMIC MODEL OF DAMAR AGROFOREST IN SUMATRA (INDONESIA)

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ABSTRACT

The complex structure of the Damar agroforest illustrates the intense competition for light that goes on in this environment, in which other climatic factors are not limiting at most time of the year. To assess the importance of canopy openness which determines not only light distribution amongst individual trees but also other local microclimatic factors such as temperature and relative air humidity, a three-dimensional model was developed. This individual-based model simulates forest dynamics on the basis of establishment, growth and death of individual trees. Modelling is indeed a valuable tool to test the consistency of functioning hypotheses one can hardly test in the field given the lack of controlled conditions and given the long-term response one must expect in dealing with trees.

At the present stage, the model is just a demonstration model with little connection to real data. The model simulates on a one hectare plot on a yearly basis showing the functioning of a virtual patch of forest made of a few tree species with contrasted growth habits. Rules governing recruitment, growth and death depend on the local conditions of growth prevailing for each tree. Such local conditions are assessed by calculating the crown position index of each tree which is made possible through the 3D representation of the canopy.

The outputs include population characteristics such as the distribution of crown diameter, the distribution of tree height, death rates, etc.... and individual characteristics such as growth curves. A real time graphic visualisation allows the user to inspect any subgroup of trees at any time by selecting them with the mouse on the screen.

At present results are confined to the model itself (sensitivity analysis, general behaviour). The ongoing research focuses on incorporating indigenous knowledge on "temperament" of the different species (the set of growth-and-development reactions shown by a tree towards its environment during its life cycle) and validation of the model with data from permanent plots. A module of calculation of light interception will also be added in order to test to what extent the Crown Position index is a good indicator of the light perceived by a given tree.

Key words : Agroforest, competition, individual-based modelling, light

BACKGROUND AND GENERAL OBJECTIVES

This study is part of a boarder program on Indonesian cultivated forests which has started more than 10 years ago (De Foresta & Michon 1990 & 1994; Gouyon *et al.* 1993; Mary & Michon 1987; Michon 1985; Michon & Bompard 1987; Michon *et al.* 1995). These agroforests usually show a high botanical richness and a multi-layered vertical structure quite close to natural rainforest. Different types of agroforests may be distinguished according to the main tree species. The dominant species may be damar trees (*Shorea javanica*) tapped to collect resin, *Hevea brasiliensis* grown for latex, fruit trees (duku, durian, rambutan, jacktree, etc.) or timber trees. Numerous secondary species yield many different resources (fibers, vegetables, spices, medicines, etc.) some of which are being commercialized.

Damar agroforests are probably the most studied and therefore the best known agroforests. These agroforests are facing rapid changes due (in particular) to the emergence of a new market for damar wood. Thereafter logging activity is getting more and more common. Is this new activity ecologically sustainable and under what conditions? Such is, very schematically, the type of questions we are asked. In other words our main concern lies in the conditions of viability of this agroforestry strategy to manage forest resources, and ultimately the conditions of transposability of such a strategy. We focus here on the ecological constraints of the system. Nevertheless we do believe that social and economic characteristics are often of prime importance in determining whether or not the biological potential can be realized by farmers living in the real world.

HYPOTESES AND METHOD

1. Basic assumptions

The very complex structure of the natural forest (and to a lesser extent of the agroforest) illustrates the intense competition for light that goes on in this environment, in which other climatic factors are not limiting at any time of the year, allowing vegetation to achieve an extraordinary luxuriance and biomass (Leigh 1975). The amount of sunlight filtering through the many layers of foliage in a tropical rain forest is small: less than 1% of the light perceived at the top of the canopy reaches the ground (Alexandre 1982). The importance of gaps in the canopy which provides temporarily well-illuminated places at ground level is vital to the regeneration of most of the forest constituent plants (Riera 1995). Other factors such as nutrient availability may be limiting and may affect overall growth, nevertheless competition for light is certainly a key factor in orienting the dynamics of the natural rain forest. Can light be assigned such an important role in orienting dynamics in Damar agroforest ? If so, is the crown position inside the canopy a good indicator of the light received by a tree? If not what other major ecological characteristics should be considered in order to optimize agroforest design and management? Understanding agroforest dynamics may as well give us some insight in processes going on in natural forests. Yet from a practical point of view agroforests show two major advantages over natural forests. The specific composition is much simpler (indeed 4 or 5 different species may account for as much as 90% of the total population) and significant indigenous knowledge on the ecology of the different species is readily available from the farmers.

2. Modeling technique

An important characteristic of the present situation lies in its instability: sylvicultural practices are changing rapidly due to the changing social and economic environment. Another characteristic of these agroforests is the spatial heterogenecity which is a consequence of the complex structure of the multi-species forest but also of the small size of the parcels of land combined'with a great variety of sylvicultural practices. Therefore, classical modeling techniques of population dynamics using transition matrices, or integro-differential formalism seem to be inadequate as they are limited in dealing with spatio-temporal variability. An individual-based model seems well suited to the present case (Huston *et al.* 1988, and De Angelis & Gross 1992 for some general references on individual based modeling). Indeed such a model is designed at a local scale and thus can take into account the variability encountered. In such a bottom-up approach, population dynamics characteristics such a recruitment or mortality, result from the interaction of the elementary components (i.e. the trees). Of course, the first step in such an approach is to make clear in what way the trees interact. A computer program may then be used as a virtual laboratory to test the hypotheses made or to explore new situations, etc. It may also be used to assess the analytical techniques (in particular statistical techniques) used to study the real world by testing them on the entirely controlled and reconstructed artificial ecosystem.

MODEL

1. Outline

At the present stage the model is just a demonstration model with only abstract connections with real world. The model simulates on a one hectare plot and on a yearly basis the functioning of a virtual patch of forest made of 4 different tree species with different ecological requirements. Border effects are handled by considering a toric representation of the plot surface[1] : trees on one edge are considered as neighbors of the trees of the opposite edge of the quadrangular plot. Each tree species obeys specific rules governing recruitment, growth and death. These rules are parameterised according to the local conditions of growth prevailing for each tree. The program is developed using Visual Works, an object oriented language. The outputs of the model include population characteristics for the different species, such as the distribution of crown radius, distribution of tree height,

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[1] A tore may be defined as the R3 surface generated by the rotation of a circle around a straight line belonging to the circle's plan but not intersecting with the circle

distribution of crown position and crown form indices, mortality-census, etc., and individual characteristics such as growth curves. A real time graphic visualization allows the user to inspect any subgroup of trees at any time by selecting them with the mouse on a map of the plot. A simple parallel projection of the selected subgroup of trees is also available. Such a graphic interface proved to be useful during the sensitivity analysis at a local scale.

2. Tree characteristics

A set of variables is assigned to each tree. Some of them are strictly individual, some are common to all the trees of the same species. Species attributes include a subset of geometrical parameters that define the general crown shape (relation between horizontal and vertical crown radii), the allometric relation between crown extension and tree height in optimal growing conditions, maximum crown extension and maximum tree height. The way in which the tree reacts to its environment (tolerance to shade and full sunlight at different stages) is also defined at the specific level. Potential growth curves are also determined at the species level. Individual tree attributes include geographical coordinates, current dimension and age, record of previous growth and a list of neighbors. Two additional variables are calculated at each time step for every tree from the former variables: a Crown Form index and a Crown Position index.

3. Growth

At each step in time, an attempt to grow is made by every tree. Growth is successful if no collision arises between the growing tree crown and neighboring crowns. Growth is computed in a two step process. First an attempt is made to grow in height. If growth in height is successful then an attempt is made to increase the crown volume.

Both height increment and crown radius increment follow Chapman-Richards functions, broadly used to describe tree growth, which is an expression of the form:

(i) $x = a^* (1 - b^*\exp(-k^*t)^c$

where k is a scale factor, a the asymptotic value, b and c parameters responsible for the shape of the growth curve.

Identifying finite difference and differential, (i) may be rewritten as the rate of change per unit of time

(ii) $\Delta x = c^* k^* x^* ((a/x)^{(1/c)} - 1)$

In this form, the growth increment no longer depends on age but only on size. Thus, it becomes possible to untie age and growth rate and account for temporary stops or pronounced slowdowns in growth which may occur in unfavorable conditions when space or light resources become insufficient. A vigorous re-growth may occur once better conditions are recovered (Cluzeau 1992; Schutz 1989). Nevertheless, this compression ability and the speed at which a tree will recover depends on the tree species. Such refinements may be incorporated in later versions.

Growth in diameter may also be defined as following a Chapman-Richards function but has not yet been implemented. Parameters for the different species were set as shown in Table 1.

Table 1. Default growth parameters for the different species (see text for explanation)

	Height			crown	vertical	radius
	c1	a1 (m)	k1 (yr^{-1})	c2	a2 (m)	k2 (yr^{-1})
Damar	2	48	0.04	1.22	12	0.04
Durian	2	48	0.04	1.74	18	0.04
Duku	2	30	0.02	2	12.5	0.02
Pioneer	2	30	0.08	2	2	0.08

Horizontal crown radius (hr) is computed as a function of the vertical radius (vr) (Table 2).

Table 2. Relation between horizontal crown radius (hr) and vertical crown radius vr

Damar	hr = vr* (1/9+2/17*vr
Duku	hr = vr / 2
Durian	hr = vr / 2
Pioneer	hr = vr*4

These functions define the maximum potential growth. This potential growth is restricted by stress indices to calculate the actual growth. Following the pioneering work of (Dawkins 1958; Alder & Synnot 1992) we consider two types of growth reducers. The first one is a function of the Crown Form index and the second one a function of the Crown Position index. The former index is an architectural characteristic and reflects the development history of the tree. The latter, which depends on the relative position of the crown within the canopy, reflects the conditions of growth prevailing at a particular moment.

The Crown Form index merely measures the relative development of the crown compared to the total height of the tree. It is indicative of the general vigor of the tree. It may be correlated both to growth increment and mortality

(Dawkins 1966 *In*: Gourlet-Fleury 1992). The following Crown Form scores are defined (Alder & Synnot 1992):

5 = Perfect : The best size and development generally seen, wide, circular in plan, symmetrical

4 = Good : Very near ideal, sylviculturally satisfactory, but with some slight defect of symmetry or some dead branch tips.

3 = Tolerable : Just sylviculturally satisfactory, distinctly asymmetrical or thin, but apparently capable of improvement if given more space.

2 = Poor : Distinctly unsatisfactory, with extensive dieback, strong asymmetry and few branches but probably capable of surviving.

1 = Very Poor : Definitely degenerating or suppressed, or badly damaged, and probably incapable of increasing its growth rate or responding to liberation.

In this classification the degree of the crown appears to be a key factor. Indeed restriction in growth of the crown is often asymmetrical when it is related to over-crowding of the surrounding space. Nevertheless, in the model, in order to reduce computing time crown is kept symmetrical around its vertical axis. A crown with poor Crown Form index will thus be represented as shrunk instead of asymmetrical (a situation rather common in dense plantations for example, where competition for space may be considered as isotropic in first approximation). The crown form index is simply computed as the ratio between the actual crown volume and the potential crown volume defined by the actual height, rounded to the nearest lower integer multiplied by 5.

The first stress index called *red*1 is a simple linear function of the Crown Form index (CF) and varies between 1/5 and 1. The same stress index is applied to growth in height and crown enlargement.

(iii) $red1 = CF/5$

The Crown Position index is indicative of the competitive status for light interception, it is based on DAWKINS crown classification (1958).,

5 = Emergent : Crown plan exposed vertically and free from lateral competition at least within the 90^{o} inverted cone subtended by the crown base.

4 = Full overhead light : Crown plan fully exposed vertically but adjacent to other crowns of equal or greater height within the 90^{o} cone.

3 = **Some overhead light** : Crown partially shaded vertically but main axis not overtopped.

2 = **Some side light** : Main axis overtopped (little overhead light) but at least one third of the 24 sampled directions around the tree (12 azimuths combined with 2 inclinations 45 and 75 degrees) is free from neighboring crown.

1 = **No direct light** : Main axis overtopped and more than 2/3 of the surrounding directions are not free from neighboring crowns.

Two stress indices are calculated using the Crown Position index. One applies to the growth in height and the other one applies to the growth of the crown radius. These stress indices are calculated according to the temperament of each species. For example, a shade tolerant species will not benefit much from a full exposition to sunlight. On the other hand a light demanding species will suffer much more from a bad Crown Position index.

The proposed general expression of *red2* (height reducer) and *red3* (crown extension reducer) are as follows (and see also Figure 1):

(iv) *red2* or *red3* = $(CP/5)^i$ with $i>1$ for light demanding species, $i<1$ for shade tolerant species, and $i=1$ for intermediate.

Default values were set as indicated below:

Pioneer tree : *red2* = *red3* = $(CP/5)^2$ species very sensitive to shading
Duku : *red2* = *red3* = $(CP/5)^{0.5}$ shade tolerant species
Durian, Damar : *red2* = 1, *red3* = CP/5 intermediate requirement for light

In the case of Damar and Duku there is no direct reduction in height growth resulting from poor Crown Position index. The tree continues to grow in height but since the crown extension is reduced, the Crown Form index in turn soon suffers from this increase in slenderness and ultimately growth in height may be reduced.

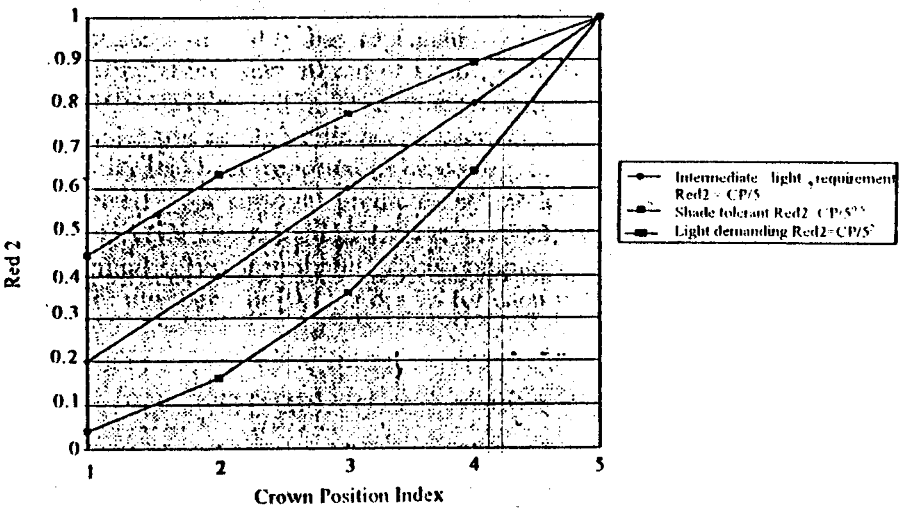


Figure 1. Growth reducer *red2* as a function of the Crown Position index

4. Recruitment

The earliest development stage considered in the model is the sapling stage (no seeds nor seedlings). Recruitment procedure is split into two separate steps. The first step consists in making the decision of recruitment, the second step is the attempt at recruitment.

The decision of recruitment may result from global characteristics (such is the case for Damar and Duku) or local characteristics (such is the case for pioneer species). In case of non Pioneer species, the number of attempts at recruitment of a tree of a given species is a linear function of the number of trees which have reached the reproductive stage (recruitment rate is set to be equal to 0.05 for all three species). This stage is defined as a given age for the different species (15 years for Duku and Durian, 25 years for Damar). It should be stressed that regeneration is not an entirely natural process. It is even largely controlled in the case of Damar which is often planted. Specific algorithms at the step of making a decision of recruitment should be developed to simulate the management by the farmer (planting, clearing ....).

Once the decision of recruitment is made an attempt at recruitment is made. Recruitment will be successful if the new sapling crown does not collide with any existing crown (the same constraint applies to all species) and if its Crown Position index is propitious, which depends on the species temperament. Favourable CP index for Damar and Durian was set between 2 and 5, while it was set between 1 and 4 for Duku which is supposedly less tolerant to intense exposure to sunlight during the early stages of development.

To manage the case of the Pioneer species whose individuals settle in open space the plot is divided into elementary quadrats of 10 m x 10 m. If a quadrat stays free at the ground level for 5 time steps then an attempt of recruitment of a Pioneer tree is made. Recruitment is successful if the new crown does not collide with other crowns and if the Crown Position index is at least equal to 4 (need for high irradiance). The 5 time steps lag stands for the 5-year period needed for a germinating seed to become a young sapling of a few meters high.

5. Mortality

Mortality may be "primary" or due to tree fall. Primary mortality is simulated by applying a survival test at each iteration to each tree. It is well known that seedlings and young saplings suffer high mortality rates (Rollet 1969; Sarukhan 1980; Swaine 1989). Nonetheless mortality has repeatedly been reported to be independent of tree size for tree measuring more than 10 cm of Diameter at Breast Height (Swaine 1989; Manokaran & Kochumen 1987). Thus this survival probability is set independent of the tree size in the model since only saplings and later stages are considered.

Mortality has been reported to be correlated with growth rate (Swaine 1989) and has often been used as a survival predictor by modellers : Buchman 1979; Ek & Monserud 1979; Hann 1980; Buchman *et al.* 1983; Wan Razali 1988 *in* Vanclay 1990. Thus the annual survival probability S is computed as a function of stress indices. Each time step a random number r in [0, 1] is drawn for each individual and the tree is supposed to survive if $r < S$.

(v) for a Pioneer tree : $S = 0.995 * (((CF/5 * (CP/5)^2))^{0.025}$ (Figure 2a)
(vi) for Duku : $S = 0.995 * ((CF/5) * (1.2 - CP/5)^{0.025}$ (Figure 2b)
(vii) for Durian and Damar : $S = 0.995 * (CF/5)^{0.025}$

The shape of these functions are shown on Figure 2 for Pioneer and Duku.

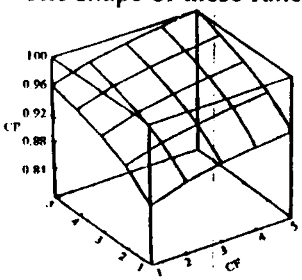


Figure 2a. Pioneer survival probability as a function of Crown Position (CP) and Crown Form (CF) indices

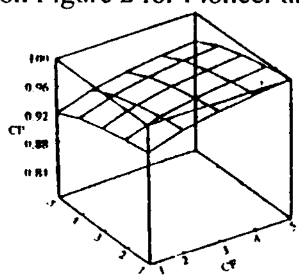


Figure 2b. Duku survival probability as function of Crown Position (CP) and Crown Form (CF) indices

Pioneer trees are submitted to increase mortality in case of low Crown Position index. This reflects their strict dependence on high light regimes. On the contrary Duku are submitted to increase mortality in case of high Crown Position index, as it is a typical understorey species.

Sylvicultural practices (age of first tapping, frequency of tapping, logging, etc.) will undoubtedly have some influence on the survival probability and should be taken into account in later versions. Varying life expectancies between species should also be dealt with explicitly in later versions.

Secondary mortality, due to tree fall, is also considered. When a tree falls the following algorithm is applied with a constant probability (0.5). A direction of fall is randomly chosen. All neighboring trees located in a 60° sector whose radius is equal to the height of the fallen tree are submitted to a survival test with a constant probability of 0.5, if their height is less than the height of the fallen tree. It would also be possible to consider lighter damages due to tree fall such as branch breakage by reducing CF

PRELIMINARY RESULTS

1. Sensitivity analysis

Planting density

The outcome of competition between two or more neighboring trees appears to be very sensitive to the planting distance. Figure 3a shows the silhouette of 6 Damar trees planted two by two at varying distances, after 100 time steps. For the sake of convenience recruitment and mortality were prevented during this simulation. Similarly, trees are dealt with in the same fixed order during the whole simulation whereas normally this order is randomly changed at each time step.

When planted 3 m apart neither of the trees takes a definite advantage on the other and both grow slowly in height but fail to develop their crown to any significant extent. Planted 5 m apart, one tree quickly surpasses the other in height but not enough to overtake it. Finally the lower tree has the more developed crown.

Competition occurs for space and light. The critical point here is probably competition for space. When the crowns of two neighboring trees of same height come into contact, the ability of a tree to overtop and then overtake its rival will depend on the rate of the growth in height at that moment and on the crown shape (mainly the lateral curvature radius). The interesting point here is that the response to increasing distance between trees is not continuous nor even monotonous.

Crown shape

The same spacing pattern applied to Durian which has the same temperament as Damar but different geometrical characteristics, lead to a different outcome as shown in Figure 3b. In this case, the first tree to grow always overtops the other but the latter may or may not become suppressed depending on the distance between the trees. Contrary to Damar crown which flattens with aging, Durian crown has a fixed shape (see Table 2). This shape determines a curvature radius inferior to Damar at an early stage, but superior to Damar at a later stage. Figures 3c and 3d show the patterns found for competing Duku trees and competing Pioneer trees in similar conditions. In the first case no stratification occurs, whereas it is systematically the case for Pioneer trees. Here the growth rate (low for Duku and high for the Pioneer tree) and the crown shape (ellipsoid with its big axis vertical for Duku, and big axis horizontal for the Pioneer tree) combine to give the patterns as shown on Figures 3c and 3d.

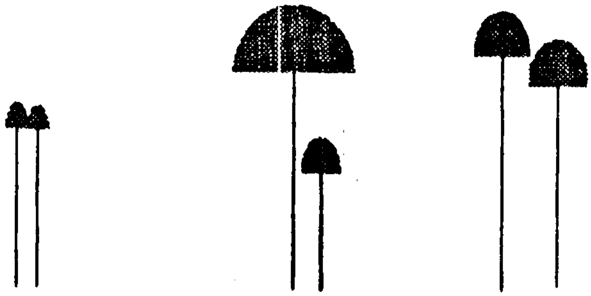


Figure 3a: Damar

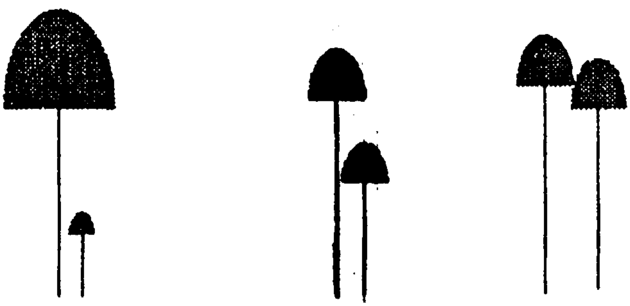


Figure 3b : Durian

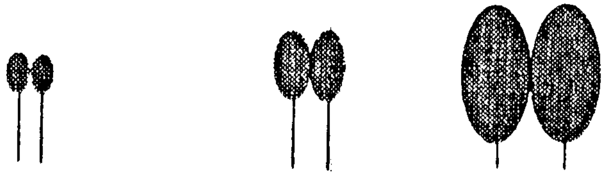


Figure 3c : Duku

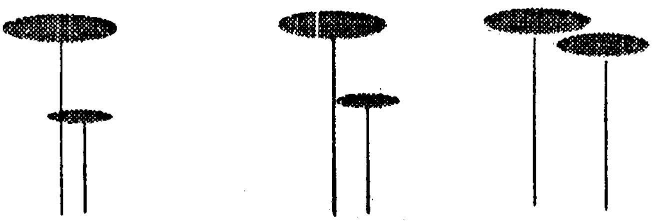


Figure 3d : Pioneer

Figure 3. Effect of planting distance on competition (100 time steps)

Crown Form index

CF index is computed as a function of the ratio of the actual crown volume to the potential crown volume. This leads to the consideration as belonging to class I trees with a crown volume less than 20 percent of the potential crown volume. This is equivalent to a crown radius less than 58 percent ($0.2^{0.33}$) of the potential crown radius. It is likely that this class is too broad : it is rather counter intuitive that trees with half the potential crown radius would have just the same behavior as trees with one tenth of the potential crown radius.

CF index directly influences mortality rate through the mortality function (see 3.5). As such it is a very sensitive parameter. When mortality and recruitment are precluded then the effect of CF on the dynamic of growth itself may be assessed. A comparison between two simulations using two different ways of computing the CF index (either as a function of the ratio of the actual crown volume to the potential crown volume or as the same function of the ratio of the actual crown radius to the potential crown radius) reveals only minor differences in growth dynamic during 100 time steps. This is related to the fact that CF index affects growth of all tree species in the same way (see 3.3). Thus the major influence of CF seems to be on mortality rate.

Distance of interaction

The standard distance of interaction was set to 50 m. This, value is derived from the way the Crown Position index is computed : a 45 degree angle between the bottom of the crown of the smallest tree and the top of the crown of the biggest possible tree would put them at a distance of 47 m. The calculation of the mortality due to tree fall also makes use of the neighbors in a sector of 48 m radius (maximum height).

Since the number of potentially interacting trees increases like the second power of the distance of interaction, it is worthwhile trying to reduce this interaction distance in order to reduce computation time. Preliminary tests have shown that, apart from the effect on mortality rate (mediated through the computation of secondary mortality), the distance of interaction may well be reduced to 20 m without major changes in overall dynamics. Should this result be confirmed, it would then be useful to address tree fall damages by keeping track of the current spatial distribution of trees by means of a discrete representation of space (record of cells in a grid) instead of a list of neighbors.

2. General behavior

General model behavior is at first sight rather satisfactory. Crown radius, Crown Position and Crown form index distributions seem to have reasonable shape, total number of trees and overall dynamics of growth also compares well to the available data from permanent plots. Individual growth curves show a high variability as expected (Figure 4). Nonetheless some outputs require further examination.

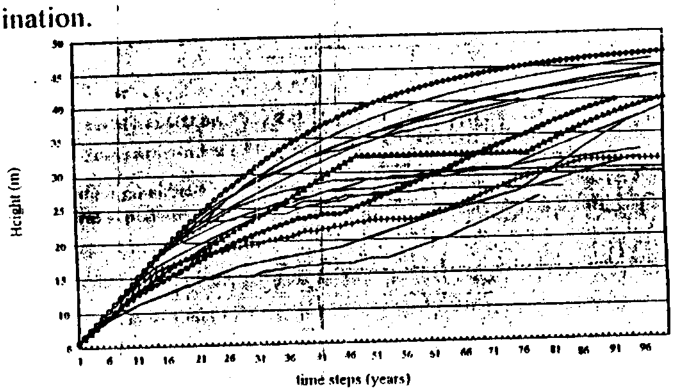


Figure 4. Sample of simulated growth curves in height for Damar

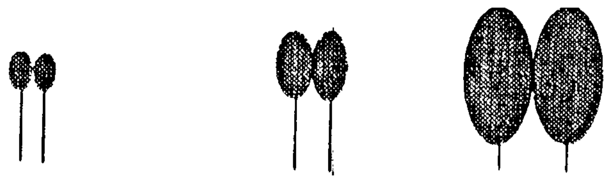
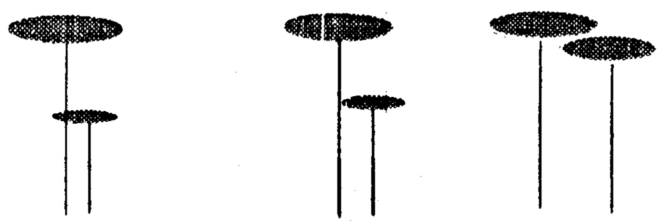


Figure 3c : Duku



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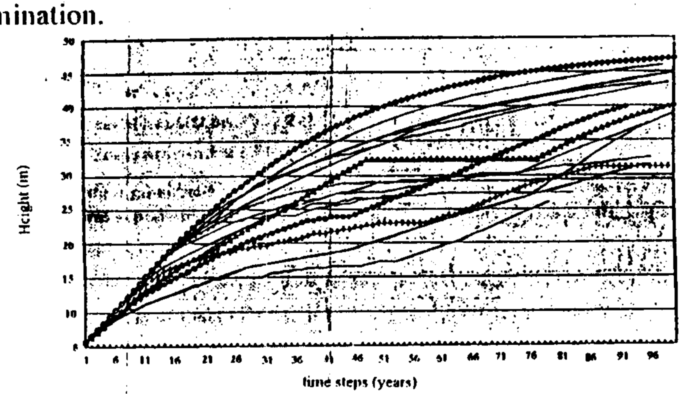

Figure 4. Sample of simulated growth curves in height for Damar

Crown Area Index

The CAI is computed as the ratio of the sum of all crown projections on the ground to the total ground area. CAI after 100 time steps reaches 0.9 which seems rather low. Of course the CAI is strongly constrained by the symmetrical shape of the trees wheteas in the real world trees may show strong asymmetrical growth to fill adjacent gaps in the canopy. Nevertheless, a single layer of non overlapping adjacent discs of a fixed size would cover about 75 percent of the area irrespective to their size. A combination of circles of different sizes would then cover even more than 75 percent of the area. Thus one would expect a two layer canopy to reach a CAI of ca 1.5. The low value of CAI may be due to the high number of gaps one can notice on a map of a typical simulated plot (Figure 5). This may result in part from the randomized location of recruited seedling whereas in a managed forest these seedlings whether planted or selected certainly do not follow a randomized pattern. But this may also result partly from too high mortality rates.

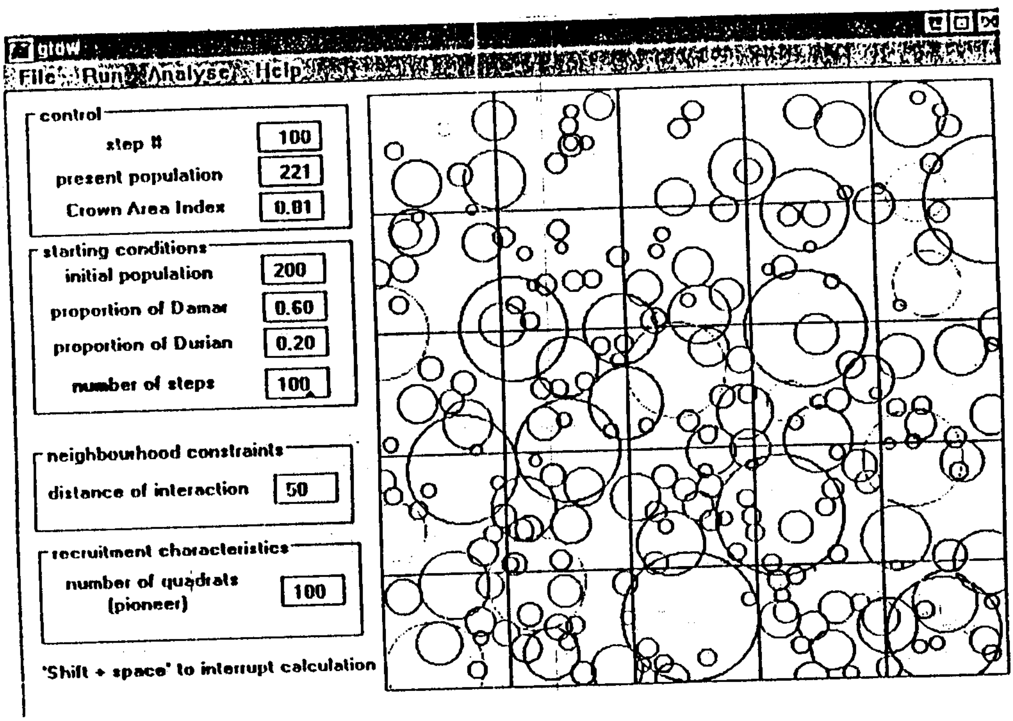

Figure 5. A map of a simulated plot after 100 time steps.

Mortality rates

Average mortality rates for different species are shown on Figure 6. The mean overall mortality rate is *ca.* 2% which is quite high. A careful examination of available data to assess the relative importance of primary versus secondary mortality, and mortality due to felling versus natural mortality has still to be done. Recruitment rates and location of new saplings should also receive careful attention. Figure 6 exhibits rather lower mortality rates for Duku and Pioneer trees in the first (and more numerous) class. This is probably related to the distribution of Crown Form indices of these species which are severely right skewed compared to the others (Figure 7). This is due to the fact that growth in height parallels crown extension in case of inadequate light regime contrary to the case of Damar and Durian. This compensates for the increased mortality due to sensitivity to Crown Position index (see 3.5). As a consequence specific composition evolves only slowly over time (Figure 8).

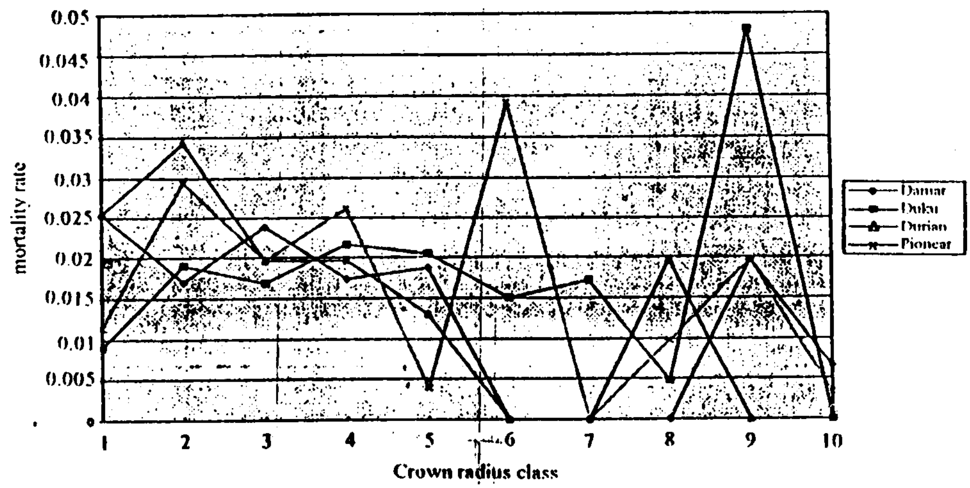

Figure 6. Mean mortality rates between simulation steps 100 and 150.

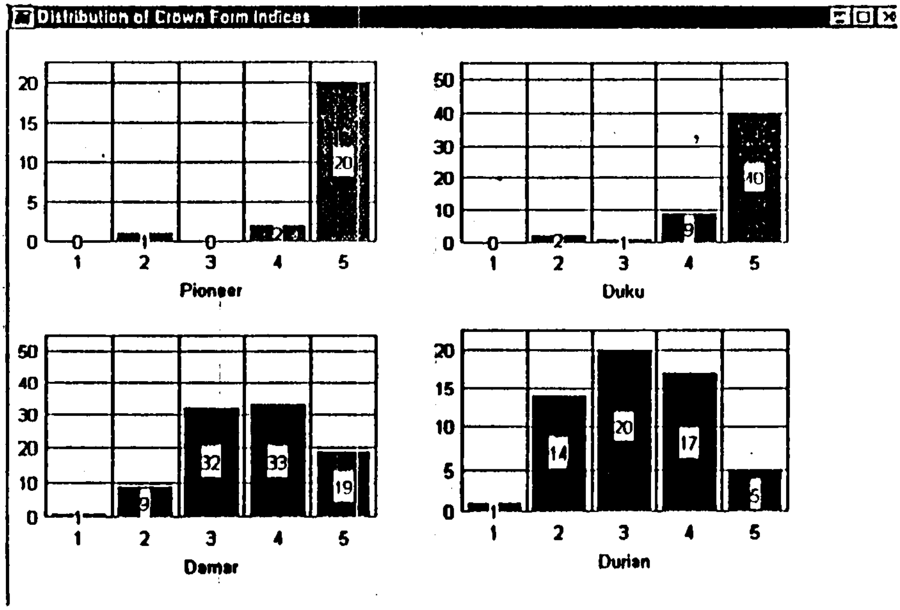

Figure 7. Typical distributions of Crown Form indices after 150 time steps.

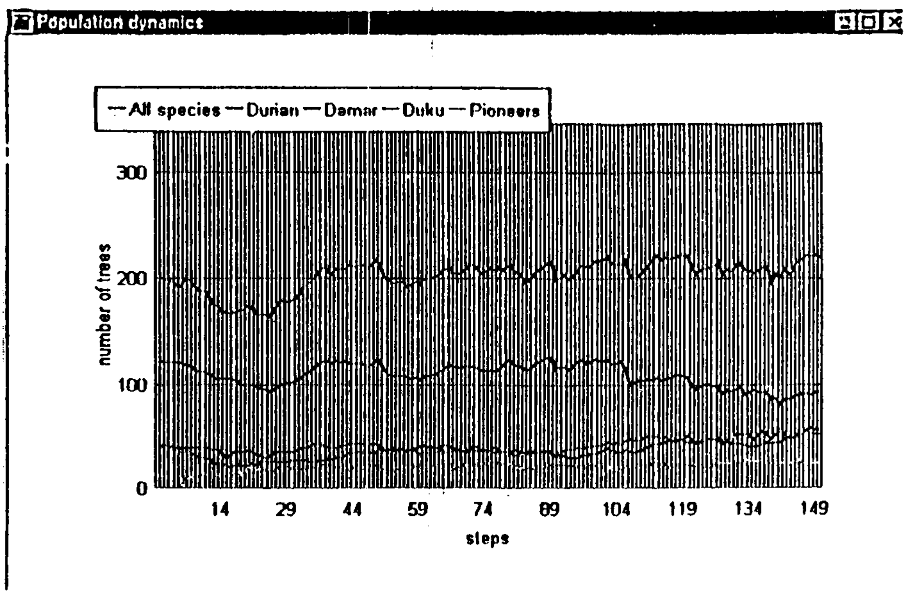

Figure 8. Specific composition evolution across 150 time steps simulation

FUTURE PROSPECTS

1. Necessary improvements

Some substantial though quite straightforward improvement of the model will be achieved through the analysis of data collected from 3 one hectare permanent plots started 3 years ago. These data include DBH increment and Crown indices. Tree height and crown extension can easily and usefully be added to this set of measurement during the next campaign. The high sensitivity to crown shape claims special attention. Potential growth curves of height and of crown volume also need sound estimates. This will be achieved through the study of the morphology of existing trees of different development stage grown in favorable conditions. Measured variables will include: total height, crown projection on the floor approximated by an octagon, height of maximum crown width, and DBH. Taken as a body, these measures should allow to monitor the progressive change in shape which occurs in many species with aging : the slow loss of apical control by the main shoot (shapes becomes more excurrent) and the natural pruning of the lower branches.

Another major thrust of our future work should be the incorporation of the farmers management practices and their ecological knowledge into the model. This objective may be attained through sample surveys.

2. Validation

The main hypothesis made in the model concerning the functioning of the forest is the prevailing importance of light. Indeed light is assigned a crucial role in orienting the global dynamic through the crown position index which has an influence on recruitment, growth and mortality all at the time.

To what extent is the Crown Position index implemented in the model, a good indicator of the amount of light perceived by a tree? This question may be addressed by adding a module to simulate the radiation transmission through the canopy and calculate the amount of light available to each tree. This module may be calibrated and validated independently from the growth model itself by using hemispherical photographs. This first step validation process might as well lead to a reconsideration of the geometrical representation of the tree (the symmetrical shape of a crown may appear to be a strong constraint to get a reasonable estimate of light availability through the canopy). The second validation step will involve the growth model itself and could make use of one or two plots not used during the calibration step.

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