Growth and Yield Modelling Project

NEWSLETTER NO. 2 - *DECEMBER 1998*

Welcome to the second Growth and Yield Modelling (GYM) Newsletter, which is designed to update developments and promote advances and outputs of this DFID funded Forestry Research Project throughout its 3-year term.

The purpose of the project is to develop and apply an individual-based model to predict the growth and yield of tropical forests following management interventions. Different management options will be compared to evaluate the ecological and economic sustainability of management or silvicultural treatments. This work will be carried out through links with selected end-users in Indonesia and Malaysia. The project is linked to an international Criteria and Indicator research programme co-ordinated by the Centre for International Forestry Research (CIFOR). CIFOR will also assist in the promotion of the project outputs internationally.

Additional information about the Project is available from our WWW site and FTP sites**:**
http://meranti.ierm.ed.ac.uk/g&y/home.htm,
ftp://meranti.ierm.ed.ac.uk

Functional Classifications, Physiological Ecology and Options for Parameterising and Modifying the Hybrid Forest Model:

The following contribution is from the Institute of Terrestrial Ecology (authors: Gerry Lawson and Jan Dick).

A report is available here which introduces classifications of tropical forest vegetation; describes a range of 'gap' and process-based models of forest growth (including the ITE Hybrid forest model (Friend et al 1997 – Figure 1); considers the variation in physiology of tropical trees and the degree to which this variability can be represented in process-based models; summarises the current efforts to simplify and modularise the Hybrid model; and reports on the availability and reliability of permanent sample plot data from Indonesia.

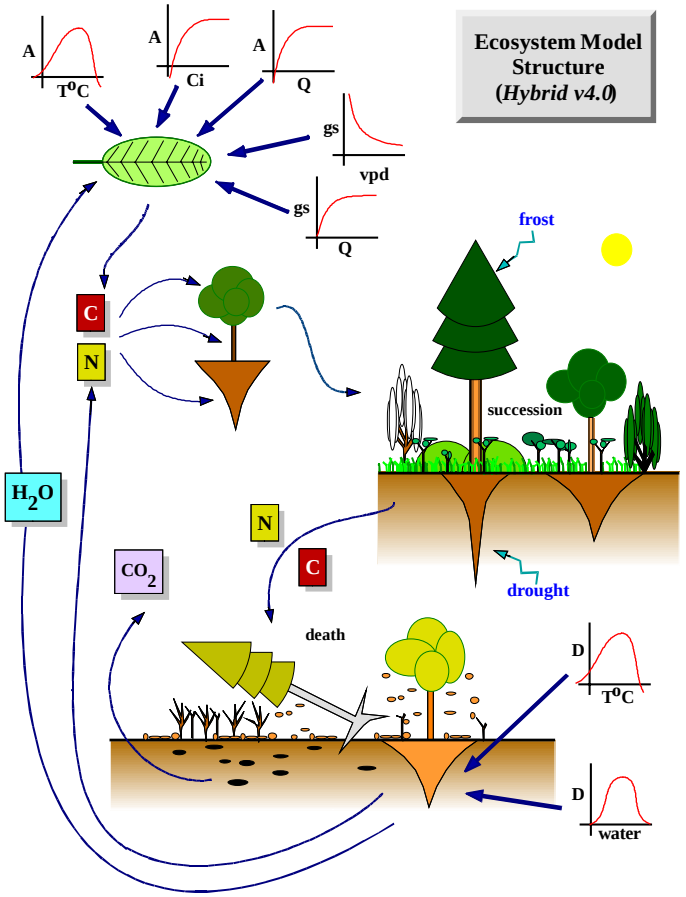

Figure 1: *Hypar 3.0 represents photosynthesis, water and nitrogen transfers within one-meter canopy layers for individual trees. Allocation of accumulated carbon to foliage, roots, wood and sapwood-storage takes place annually. Death and crown lifting is driven by negative carbon balance. The model is a 'hybrid' of a mass-balance 'big-leaf' model and competition between generalised plant types (based on the gap models ZELIG and FOREST-BGC).*

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The IERM SymFor98 modelling framework currently represents competition between individual trees using a diameter-distance competition index for neighbouring trees within a specified range. This will remain as one of the competition options, but it is intended to incorporate the code for Hybrid 'tree objects' within SymFor, and simulate the light climate in subplots as a more accurate index of competition, and as an input to seedling regeneration routines. Soil moisture and nutrient routines are also available within Hybrid and will be incorporated at a later stage. Hybrid currently requires 32 parameters to be estimated in order to represent the environmental responses of different species. Fewer parameters will be required in the modular version, but it is still very difficult to parameterise a functional model such as Hybrid with realistic parameter values for a large number of species. In Indonesian forests it is therefore likely that Hybrid will only be parameterised, and tested, for a small number of functional classes – representing species which are as similar as possible in their environmental responses and growth potential.

Long-term datasets:

Data on diameter and position of individual trees within permanent sample plots from a series of forest projects in Indonesia will be used to determine similarities in forest structure across a range of Indonesian environments. It will also form a rigorous basis for testing the outputs from the forest models. However, the wide range of species (typically 500 per hectare) indicates that this botanical identification is too detailed for the comparison exercise. Different species are clearly occupying the same function niche within the canopy structure at different sites. Therefore the development of an appropriate functional group classification is proceeding and various existing classifications are being evaluated.

Functional Groups:

Physiological factors which are relevant to functional groups of tropical trees are already partially represented in the Hybrid model:

- **Bud break:** is controlled by thermal time and soil moisture, but it may be necessary to introduce a photoperiod factor to control leaf initiation in deciduous or leaf-exchanging tropical species where this is not obviously related to soil moisture.
- **Stem elongation:** is driven by photosynthesis, carbon allocation and allometric constants linking height with stem diameter, but these constants are likely to vary with age as well as species.
- **Bud dormancy:** is driven by degree-days and interaction with frost in cold-deciduous species. Shortening day length and decreasing night temperatures may induce dormancy, but are not currently considered for dry-deciduous species.
- **Leaf loss:** in cold-deciduous species is controlled by empirical relations between latitude and daylength; and in dry-deciduous species it is triggered by soil moisture. All deciduous and evergreen tree types have a single annual leaf-turnover parameter (with partial nitrogen re-translocation). An improved representation of seasonal peaks in leaf loss may be required in tropical semi-deciduous forests.
- **Cambial growth:** is assumed by Hybrid to take place only at the end of each year, although carbon stores and maintenance respiration are derived daily. Carbon is allocated by a 'pipe-model' which holds leaf mass in proportion to cross-sectional area of living sapwood by progressively allocating available carbon to leaves, wood, roots and storage carbon. At least 10 parameters are involved in Hybrid's carbon allocation algorithms, and several will be key in distinguishing functional tree types.
- **Root growth and death:** is a great unknown for trees in natural systems, and assumptions greatly affect predicted above-ground yields. Hybrid assumes different turnover rates for coarse and fine roots, with fine-root growth proportional to foliage increment, and only 2 soil layers represented. In reality, trees change their relative allocation of photosynthate between below and above-ground growth depending on which environmental resources are limiting, and this ratio varies considerably seasonally. Such considerations are important in modelling crop-tree competition, but will be less important in predicting tropical forest growth.
- **Ageing:** is partially represented in Hybrid through its optimisation of nitrogen in canopy layers with respect to light, and the fact that photosynthetic efficiency, transpiration and respiration are partially related to nitrogen. Lower layers with a sustained negative carbon balance are assumed to fall off.
- **Flowering and Fruiting:** are not represented in Hybrid. Biomass in heavily flowering trees can occasionally represent 20-30% of biomass-increment, but flowers often photosynthise themselves, and the overall significance of carbon losses to flowers and fruits is unlikely to be significant for this project.
- **Seedling growth and death:** is controlled by the same carbon-balance considerations as with mature trees. An input parameter sets the maximum number of trees in a plot and new saplings are introduced from all available tree-types to replace mortality. The initial dbh and variability of these saplings is set with input parameters. There is scope to parameterise seedling environmental responses differently to mature trees, since this is a frequent observation in tropical forests.

Modularisation of the original Hybrid model has been initiated, and 'tree-objects' exist which exchange carbon and nitrogen exchanges calculated at sub-daily 'physiological timesteps' and allocate stores on a daily timestep. This Fotran90 code has been provided to IERM for inclusion in SymFor98.

SYMFOR 98:

This contribution is by Dr Paul Phillips (IERM)

SYMFOR 98 is now operational. This represents the completion of the first step in the process of developing individual-based models of tropical forest growth.

SYMFOR 98 is a modelling framework. In itself, it cannot model forest growth; it only specifies the way in which it enables forest growth to be modelled. Like any framework, it facilitates an action whilst also placing limitations on the way in which that action is carried out. Within this framework, the user must satisfy the requirements of each of a number of "swappable functions" by choosing an appropriate "module" written for this purpose. In addition, they can choose parameter values within a module. There may be, and in some cases already are, a number of modules from which to choose to satisfy a particular swappable function. Let's look at an example: the calculation of diameter increment. Some module must be selected for this purpose, that is invoked when the framework calls the "diameter increment" swappable function. This could be a "dummy" module, which does absolutely nothing, or it could (and should!) be a fully calibrated module which calculates and returns the growth of each tree in the modelled stand using the data structures provided by the framework. As far as the framework is concerned, it doesn't matter which is used, but the choice clearly affects the simulation results!

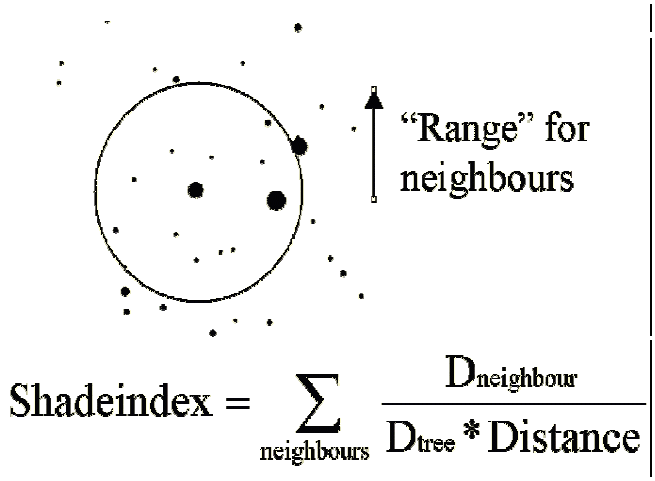

Figure 2: *An example of a module for the swappable function "shadeindex". This algorithm calculates the competition index called "shadeindex" based on a relative height-distance relationship between the tree and it's neighbours. Another swappable function defines which trees are classed as the neighbours of a particular tree.*

The framework to date accomodates several basic swappable functions: individual tree growth, regular natural mortality, ingrowth to the lowest size class and logging operations. Within these, there are more detailed swappable functions, describing the state of sub-plot gridsquares for seedling/sapling development, damage due to falling trees and skid-trail creation, competition between trees for resources and tree quantities derived from diameter.

The ability of the user to choose the functionality of the simulation at run time gives them great power. It becomes trivial to compare alternative modelling techniques. It is simple to evaluate alternative silvicultural management options. It is also simple to create results without applying any care, knowledge or expertise either of the forest or of the model within the framework; it is open to abuse. Clearly, before any results from a simulation can be trusted, the model must be calibrated and validated using extensive data. The forests simulated must be within the scope of the data used in calibration, or at least the differences must be within the validity range of the calibrated relationships. If either of these two is untrue, the results should be quoted as "preliminary" at best.

The current stage of the SYMFOR development is to calibrate all the relationships necessary to make a complete model within the framework (i.e. at least one module for each swappable function). This is no small task! It involves significant data analysis and understanding of forest processes in order to extract relationships which completely define the state and development of the forest. Initially this will be restricted to an empirical model, albeit a sophisticated one with arguably "process-based" components of competition. However, in parallel to this work GEF is being developed and will be integrated to the SYMFOR framework. Enviromental effects can then be introduced to the framework to describe processes such as water-stress on trees, topographic effects such as erosion of top-soil and climatic variations. These are the long- term targets of the project. For now, we're concentrating on developing the first individual-based tree growth model for mixed tropical forests within SYMFOR.

Further Resources:

- More project information can be found at: http://meranti.ierm.ed.ac.uk/g&y/home.htm
- SYMFOR information and help pages at: http://meranti.ierm.ed.ac.uk/symfor/hlp/contents.html
- Free downloadable version of SYMFOR at: http://meranti.ierm.ed.ac.uk/symfor/download.html

A poster presented by Dr Paul Phillips at the IUFRO conference "Process- based models for forest management" can be downloaded from: http://meranti.ierm.ed.ac.uk/g&y/collabs.htm

Project Management and Organisation:

The University of Edinburgh:

The Growth and Yield Modelling Project is managed by staff at Edinburgh University.

Dr van Gardingen leads the project. He is responsible for delivery of outputs, reporting and co-ordination between project partners.

Dr Phillips is extending an existing growth and yield model (SYMFOR).

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Institute of Terrestrial Ecology:

The Institute of Terrestrial Ecology (ITE) in Edinburgh are modifying one of their models (Hybrid) to improve the growth relationships used by SYMFOR. ITE are also responsible for the statistical analysis of PSP data.

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BPK Samarinda are responsible for the provision of the datasets and application of the growth and yield modelling system in Indonesia

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The Growth and Yield Modelling project is linked to CIFOR's Criteria and Indicator Project to develop and evaluate C&I for yield regulation in sustainably managed forests.

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The University of Edinburgh is a member of the Edinburgh Centre for Tropical Forests, an association between them and the Institute for Terrestrial Ecology, the Royal Botanic Gardens of Edinburgh, the Forestry Commission and LTS