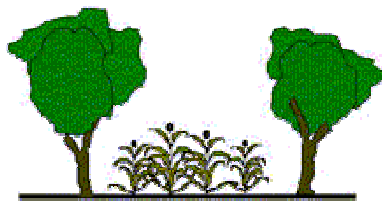


HyPARv4.1

**Model for Agroforestry Systems
User Guide**

*Hypar Version 4.1
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Preface

The HyPAR programme has been developed with funding from the UK-DFID Forestry Research Programme. HyPAR builds on previous DFID-funded work on the PARCH crop model, originally developed at Nottingham University¹, and now supported in the form of the PARCH-THIRST Model by Newcastle University². The code of HyPAR versions 1-3 was developed between 1994 and 1998 in response to workshops (Anderson et al. 1993; Lawson & McIver 1995) which concluded that models had a particular role to play in agroforestry to:

- synthesise experimental and empirical evidence on how trees and crops interact in complex systems;
- pinpoint and prioritise gaps in knowledge;
- extrapolate research results to new combinations of soil, climate, species and management - which are too numerous to be studied with field experiments;
- provide decision-support to policy makers, researchers and extension staff.

The DFID-sponsored workshops made a number of specific recommendations.

- Most agroforestry field-studies have reported phenomenological effects on productivity, but they are highly site-specific and do not describe the mechanisms involved.
- Different nutrients are limiting in different areas and climates, and more attention is needed on nutrient-water interactions, the effects of soil structure and heterogeneity, and phosphorus limitation in the humid-tropics.
- Planned comparative experiments are necessary on contrasting sites and slopes, with a wider range of agroforestry types.
- Pruning influences water uptake, root growth and canopy photosynthesis in a manner which is often crucial to the success of agroforestry, but is poorly understood.
- Light interception is comparatively well studied in forest systems (although few models include options for both complex predictions around individual trees and generalised patterns across whole fields or wooded-plots), but the partitioning of assimilates to root or shoot growth is poorly understood.

¹ <http://www.nottingham.ac.uk/environmental-modelling/>

² Young, M.D.B. & J. Gowing. (1996) "Parched-Thirst Model User Guide." University of Newcastle upon Tyne. 109 pp (email J.W.Gowing@newcastle.ac.uk).

- Species and varieties of both trees and crops can be optimised for particular locations and mixtures, and tree ideotypes should be sought with light crowns and deep roots.
- A generic agroforestry 'shell' is needed which links existing sub-models in a manner which synthesises knowledge and predicts the effects of management in a manner which allows users to test different scenarios and understand the minimum data-sets required for model predictions.
- A modular modelling framework should be developed to link alternative modules, with different levels of complexity, in a user-friendly environment.
- Models should predict long-term agricultural sustainability, and interface with socio-economic factors, including a comparison between low-yield-low-risk and high-yield-high-risk options.
- Process, system and knowledge based models should always consider the end-user.

This **User Guide** has been written with the novice user in mind and provides (a) a general overview of the HyPAR model, with guidance in parameter selection and conducting 'experiments'; (b) an explanation of the Microsoft Excel macros which are offered to assist users quickly produce graphs from the often bewildering array of output files produced; (c) a set of worked examples to explore typical experiments with the use may wish to conduct.

The **Technical Manual** contains more detail on the methods used to represent climate, soil, tree, crop and nutrient processes in the model.

The **Website** (<http://www.nbu.ac.uk/hypar>) provides copies of all manuals, previous Agroforestry Modelling Technical Reports, occasional Agroforestry Modelling Newsletters and links to other Agroforestry Modelling Sites.

The **Source Code** (Fortran 77/90) is available to interested parties, provided they are willing to make any developments and/or data available to others. We would ask to be kept informed of any successes or failures that people have in using HyPAR .

A radically rewritten version of HyPAR is under development which will offers the ICASA³ models of CERES and CROPGRO as modular alternatives to PARCH within the same modelling framework as described in this User Guide (updates will be made available through the website).

³ International Consortium for Agricultural Systems Applications (<http://www.icasanet.org/>)

1 Introduction to HyPAR

The HyPAR model incorporates code and ideas from 'Hybrid', a model of forest canopies developed by the Institute of Terrestrial Ecology (now the Centre for Ecology and Hydrology), and 'PARCH', a crop growth model developed by the University of Nottingham, particularly for application in the dry tropics.

1.1 The PARCH Model

PARCH is an acronym of the phrase 'Predicting Arable Resource Capture in Hostile environments'. The PARCH model simulates the growth, development and yield of sorghum grown in semi-arid environments. In addition, many aspects of millet and maize growth can be represented. The model considers the effects of solar radiation, atmospheric humidity, temperature, soil water availability and nutrition, on crop growth and development. Although the model is general it has been developed particularly for applications in the dry tropics.

A multi-layer water balance simulation is a key component of the model that simulates vertical redistribution of soil water, infiltration, drainage and soil evaporation. The model uses a daily time step, during which the available levels of light, water and nutrients are calculated and converted into dry matter assuming the levels for the other two environmental inputs are not limiting. Crop growth for a given day is set by whichever of the three environmental inputs is most limiting for a given day.

An index of crop stress is calculated in terms of the ratio of light to water-limited growth. This stress index is then used to control a number of the crop's stress responses, such as leaf rolling or partitioning to roots. Nutrient stress is also incorporated. Partitioning of resources between crop organs is calculated by empirically derived fractions that are adjusted according to growth stage and level of stress. Resources partitioned to the leaf canopy and root system add to leaf area and root length thereby feeding back into subsequent calculations for light interception and water uptake.

1.2 The Hybrid Model

This model is a 'hybrid' of the 'gap model' approach (Leemans 1991) which describes the irradiance environment of a forest canopy, an individual tree growth model (Friend 1995), and a model of vegetation succession (ZELIG - Urban 1990). Hybrid fully describes the daily cycling of carbon, nitrogen and water within a unit of vegetation and combines a mass-balance approach to these growth resources with the capacity to predict the relative dominance of different plant types (such as evergreen needle-leaved trees, cold deciduous broad-leaved trees and C3 or C4

grasses). Individual trees and the grass layer compete with each other for light, water and nitrogen within a 'plot' of any size. In the standard Hybrid model (V3.0 - Friend *et al* 1997) the height distribution of the leaf canopy is calculated separately for 1m-layers of individual trees (for carbon flux) or for the aggregated forest canopy (for radiation interception and water flux).

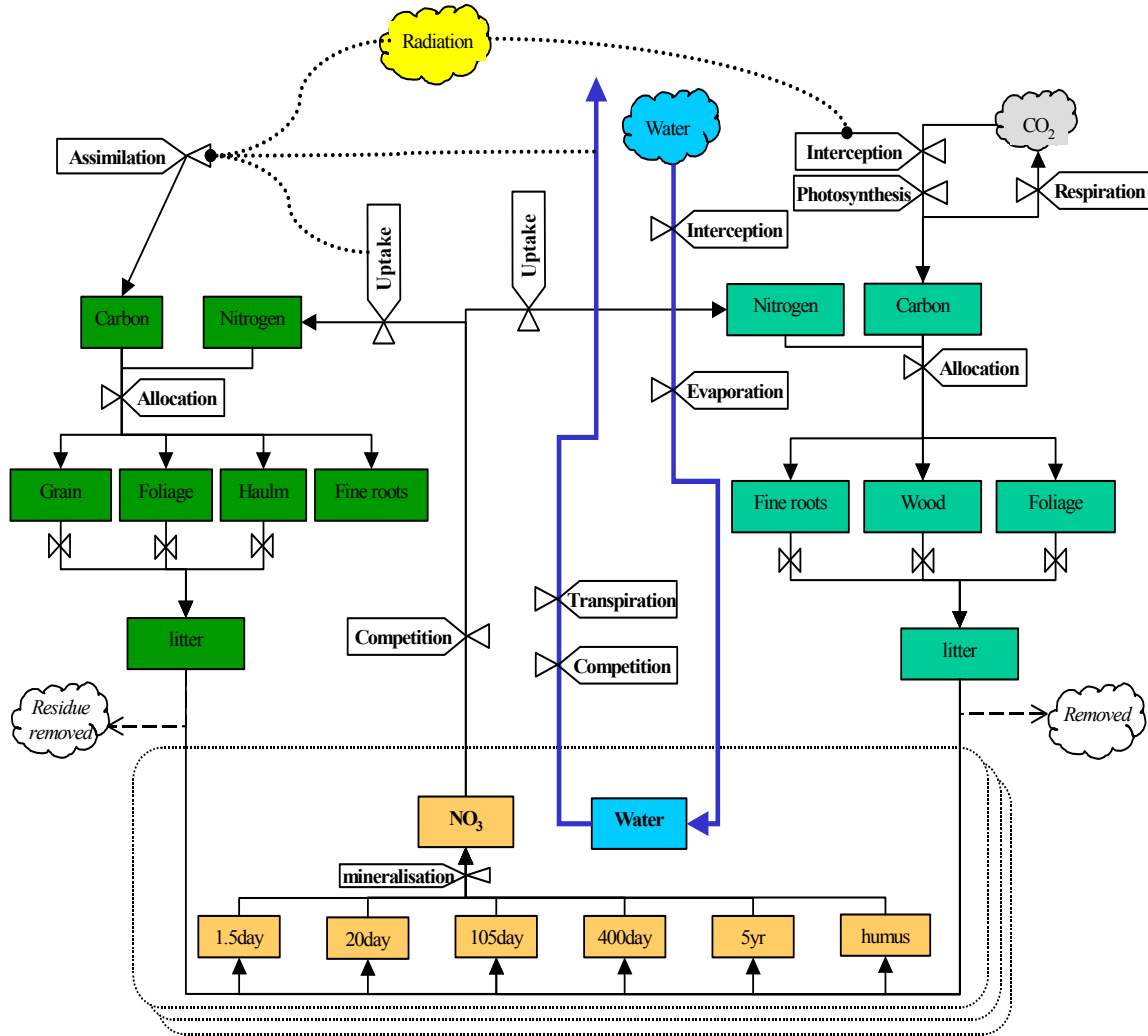


Figure 1 Diagram illustrating the main flows of carbon, water and nitrogen in HyPAR v4.1. Dashed lines represent influences on the crop assimilation processes. Solid lines are flows between compartments. Water contents and nutrient pools of different half-lives are calculated for up to 15 soil layers. Tree and crop management options, and horizontally disaggregated light interception and resource uptake are also provided.

1.3 Putting Hybrid and PARCH Together

The Hybrid and PARCH models are different in their approach to plant physiology. PARCH based on conversion efficiencies and stress factors, and Hybrid follows a more detailed energy,

water and nutrient balance approach. In addition, PARCH was originally written in BASIC and Hybrid in FORTRAN77. Combining the models presented significant initial problems, but both have been rewritten in a more modular format, largely using Fortran 90, and integration with alternative crop models (q.v.) is now significantly easier.

An overview of the processes and components represented in the HyPAR model is shown in Figure 1. The four major sections of the model are climate, soil, tree and crop, with the tree and crop parts derived from the component models. The climate sub model is based on that in Hybrid while the soil nutrient sub model is derived from PARCH. The soil water movement routines have been written specifically for HyPAR.

The HyPAR model uses ASCII input files that can be modified directly with a text editor, and the output is presented in a standard format suitable for most graphics packages. However it will more usually be run through the HyPAR Control Centre – a 'user-friendly graphical interface to guide users running the model on a PC with Windows 95, 98, 2000 or NT (Figure 2).

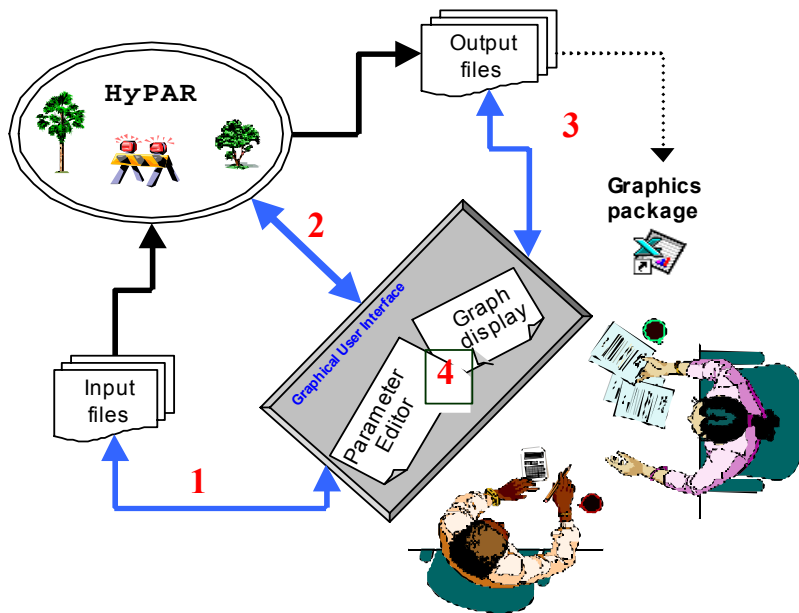


Figure 2. The graphical user interface guides users through the process of running the HyPAR model: (1) a set of menus and dialogs to enable rapid editing of the input parameters and simulation settings, and saving these settings for later use, (2) automatic running of the HyPAR executable, (3) menu selection of simple Excel summary graphs and (4) User interrogation of Excel comma separated output files to produce their own analyses and graphs.

2 Installation

2.1 System Requirements

Computer The HyPAR program can be run on any platform which supports a 32-bit FORTRAN-77/90 compiler (16-bit is not recommended due to large memory usage requirements). A processor with at least 486 performance is recommended to avoid unacceptably slow processing. The released executable is for Windows 95, 98 2000 or NT. Unix versions are no longer supported.

The Graphical User Interface 'HyPAR Control Centre' needs at least 20 Mb of memory to perform well. Users with less than this specification could run HyPAR independently of the Control Centre, but this is not recommended for novice users.

Monitor In order to display Control Centre graphics HyPAR requires a minimum of an EGA colour screen, but a Super VGA (800x600) screen is recommended to avoid problems with viewing dialog boxes and graphs.

Disk drives. The model executable code is around 1.3 Mb, the Delphi Control Centre and Excel macros for graphics add another 2 Mb. Libraries of tree, crop, and soil input parameters are also provided. Running the model can create a very large number of csv output files, so the user is recommended to have at least 40 Mb free on her hard disk.

2.2 Obtaining the program

The most up-to-date version of HyPAR is available to users who register on the website. A username and password are required to enter the download area. There is no charge, but we ask that you do not further distribute the programme. Anyone else wishing to use it should register for themselves. HyPAR can be supplied on CD-ROM, but is no longer available on floppy disks.

2.3 Installing the program

Internet. The HyPAR version 4.0 installation files are distributed within a single zipped file, hyp4setup.zip. This file should be unzipped (using "WinZip" or a similar tool) in its entirety to a local drive, and the setup.exe program contained within it run to install the application, following the on-screen instructions.

CD-ROM To install the application, run the setup.exe program on the root directory of the CD-ROM, and follow the on-screen instructions.

The application comes with its own uninstaller, which is accessed in the normal Windows 95/NT manner through the Add/Remove Programs icon in the Control Panel.

2.4 HyPAR Version number

This User Guide relates to HyPAR v4.1, if you have an older version on your hard drive, it will be overwritten by the new executable code and input files as long as these are stored in the default HyPAR directory and sub-directories. This will only be a problem if you have made significant changes to the original species, soil and crop parameter files. Advice on adapting these files is available, but HyPAR v5 (due January 2002) has such a radically different format that backwards compatibility is not guaranteed. The HyPAR Output Log Window (which appears at the end of a run) tells you what version of the core model you have.

3 A First Run Through

The HyPAR model is written in FORTRAN-77/90. It can be compiled on any platform with a fully F77-compliant compiler available. However, the easiest way to use it is through the HyPAR Control Centre, running under Windows 95, 98, 2000 or NT. The best way to understand what the HyPAR model does is to run it! Follow these step-by-step instructions to run through an example application.

3.1 Start the HyPAR Control Centre

If HyPAR has correctly installed, a program group called HyPAR Control Centre will appear on the Start/Programs menu. This contains the shortcut, which can be clicked to run the Control Centre. This provides you with the HyPAR Main Menu (Figure 3), where the horizontal toolbar allows you to run the programme (Arrow Symbol), view output graphs (Excel Symbol) or obtain help (Help Symbol). The site panel toolbar allows you to control the way the model will run. These options are divided between 7 screens : General, Climate, Crop, Tree, Soil, Nutrient & Output. For the moment do not change any of the default settings. These are stored in a number of input files, and it is these that the Control Centre edits before the programme is run.

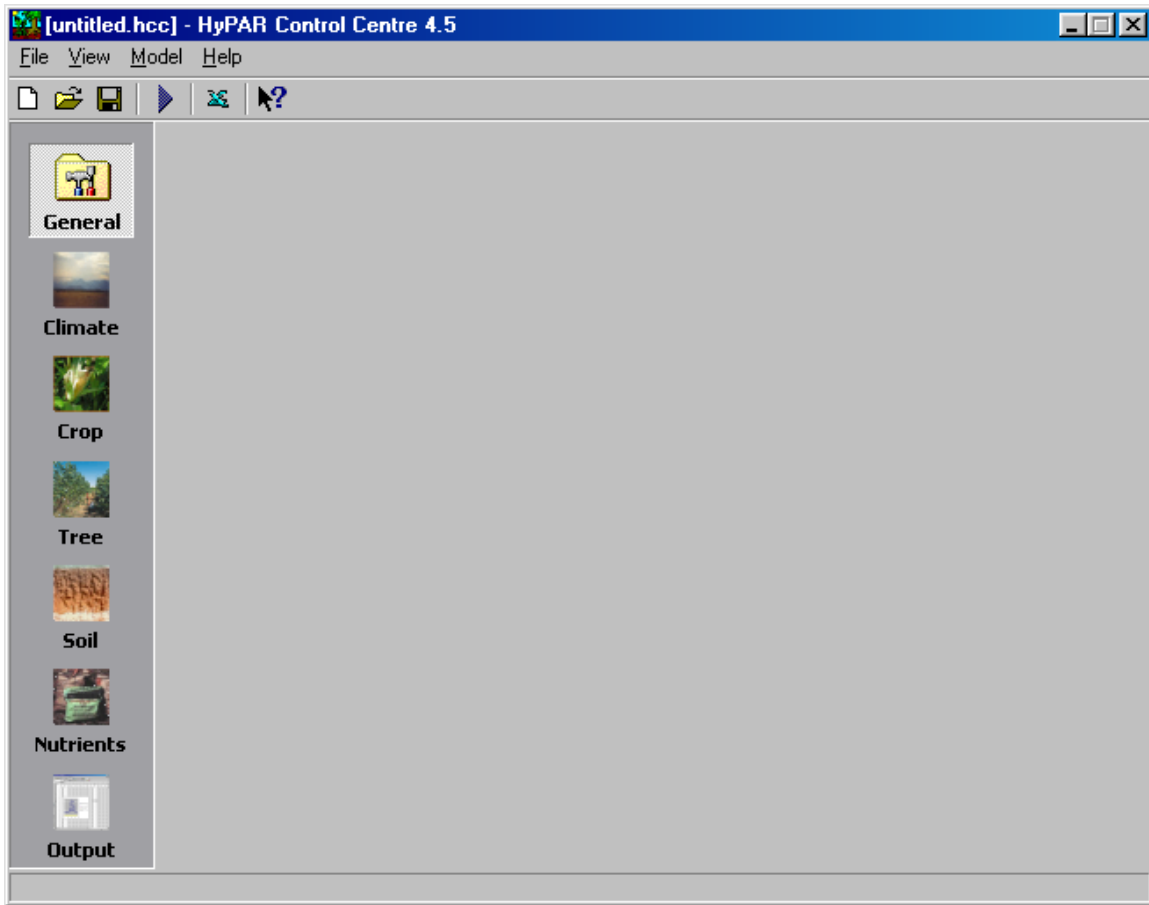


Figure 3. HyPAR Control Centre Main Window

3.2 Simulation settings

When the HyPAR Control Centre is started for the first time, it is already set-up to simulate the situation in Table 1.

Screen	Initial Conditions
General	No Trees, van Geneuchten hydrology model. Campbell pedotransfer function, latitude 11°N, longitude 24°E. 2 years simulation. field size 5 x 5m, plot size 2m.
Crop	Sorghum cultivar CSH-6A, planted at 80,000 plants per hectare, as soon as day 100 is passed and soil moisture in the top 40cm exceeds 10mm.
Tree	Although not initially switched on, two generalised eucalyptus trees are planted in the centre of two of the four plots, with initial diameters of 6.6 cm, height to base of crown 1m and no management intervention. This locational information is not used unless the 'disaggregated canopy' is selected (qv)

Climate	Weather is generated for site N09HW002, with start year 1996 (A site in Ghana)
Soil	Maximum soil depth is 15m, 4 soil types are present. These are defined by sand: silt: clay ratios rather than by detailed hydrological parameters. The soil is free draining and not sloping.
Nutrients	Phosphorus is disabled, nitrogen cycling is enabled, soil water and nitrogen levels are modified continuously rather than being reset at the end of each year, and no inorganic or organic fertilisers are applied.
Output	All possible output files are set to be saved in subdirectory 'output'.

Table 1. Initial conditions simulated in the HyPAR default input files

3.3 Run the model

Select the 'Run' Arrow on the main Toolbar. This starts the HyPAR model and displaying a dialog box showing % progress. When the run completes an Output Log is produced giving some summary information on the run. This Log simply gives a brief check on the growth and survival of trees and crops, and any error messages. If the program has halted with an error, the error message will be displayed. Full output information and optional graphics are provided elsewhere. Note down the crop grain yield each year and the rainfall levels in each of the two years. Does yield vary in response to rainfall?

Then go to the Tree Screen and check the 'Include trees at this site checkbox'. Run the model again and note what effect introducing an undisaggregated tree cover has had on crop yield.

The parameters loaded into the Control Centre for the default HyPAR run are read from files stored in the hypar/default subdirectory. Every time the model is run a file 'parameters.hcc' is created in the currently selected output folder. To reset HyPAR back to these saved settings simply 'open' this hcc file from the General Screen⁴. Note that individual tree or crop species parameters can also be saved and named separately. Before starting a new run, or 'experiment', the user should create a new output folder with a self-explanatory name. All the output files associated with this 'experiment' will be stored in this folder, together with the parameters.hcc file used to create them.

⁴ The import and export items on the File menu are for users of early versions of HyPAR and are used to read and write the old ASCII input files.

3.4 Looking at output

The information provided in the simple Output Log is not very useful, but a large number of output files are produced by default when HyPAR is run. These are stored by default as comma separated format (csv) files in the c:/hypar/output directory and can be read directly into any spreadsheet or graphics programme. However the Control Centre also provides a range of Excel Macros that produce graphs automatically. These are described in Section 13, but note that the Options Screen enables the user to choose which daily, annual and summary graphs will be produced. By default all output files are switched on. At the start of each run all files in the output folder are deleted, so users should create new folders for each new scenario they wish to test.

With a disaggregated canopy and many individual plots selected (e.g. 25) the program is very slow and the progress bar may not appear at first (although the run arrow stays depressed). Be patient! ⁵

4. Changing Parameters and Model Settings

HyPAR assumes that the agroforestry system to be modelled is contained within a rectangular field. If a disaggregated tree canopy is used, then the field is subdivided into a number of square plots. The environment experienced by the plants at the site depends on the latitude and longitude and on the soil conditions. The user must supply information about these factors as well as the species to be planted and their density.

The HyPAR Control Centre provides access to 7 screens⁶. These group parameters relating to climate, trees, crops, soil etc. and provide help on typical values. The content of each Screen and descriptions are given in the following sections. All boxes must be completed. Be careful about changing too many from the default values!

5 General Screen

This screen gives information about the location of the site to be simulated, the plot layout, the type of hydrology and pedotransfer models to use (Figure 4).

⁵ The program may also give a warning 'too many files open', and halt if too many plots are selected for daily output.

⁶ On some systems, the layout of the tabs may not be exactly as shown in the figures, for example on the Soil Screen, the initial soil water sliders may not line up directly with the layer number labels. This is a system dependent event and cannot be altered by HyPAR! If you cannot see the 'OK', 'Cancel' and 'Help' buttons in the lower right hand corner of the parameters dialogue box you need to increase the resolution of your monitor

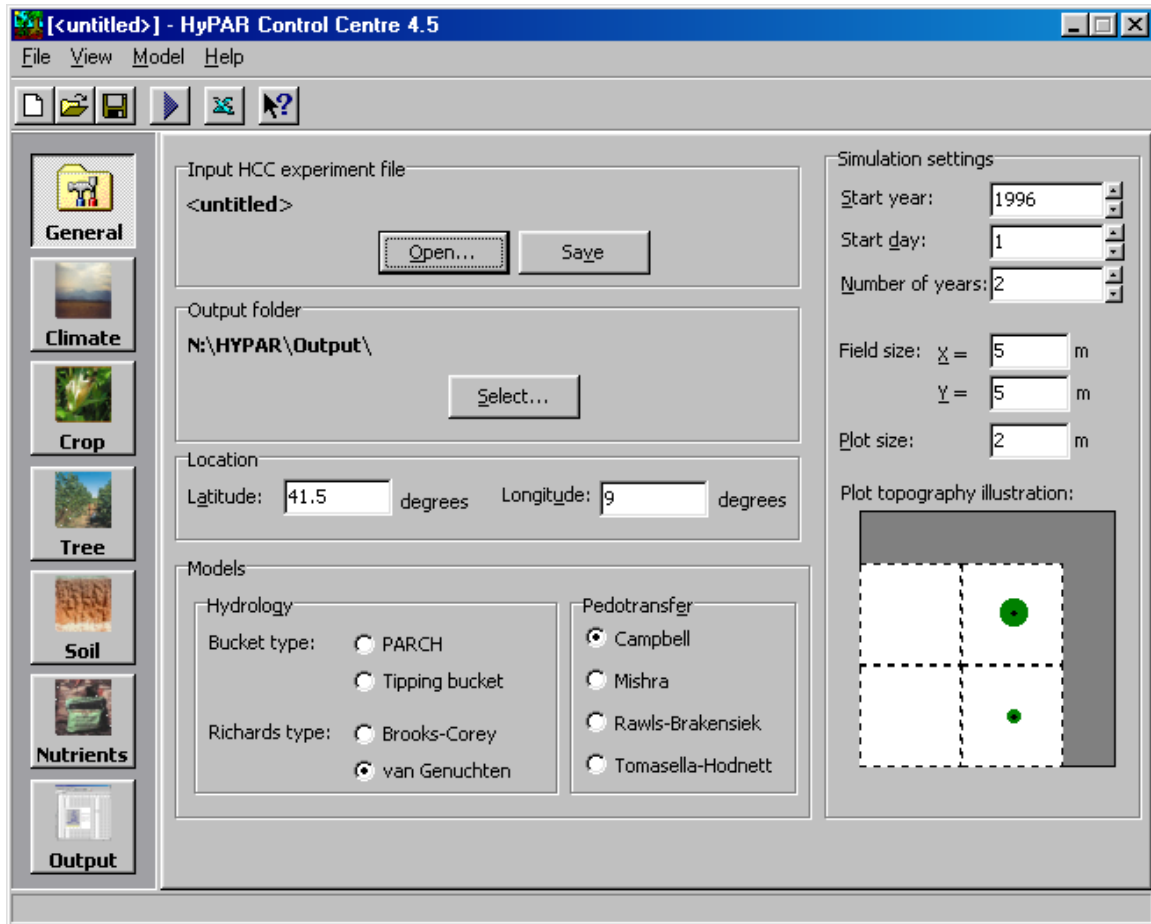


Figure 4. The General Screen

5.1 Location

Site latitude and longitude in the General Screen are used to derive solar position and day length conditions. The location given here should normally match that chosen in the Climate Screen's site editor, but may be different to allow modelling of climate change scenarios. Note that southern latitudes and western longitudes are entered as negative numbers.

5.2 Simulation Settings

The number of years and start year for simulation must be provided. Output files are produced whose name contains the simulated year. The field size is required (in metres). If the disaggregated tree-canopy option is selected plot size must also be provided. With a uniform tree-canopy selected HyPAR assumes that the plot size is equal to the field size. Up to 400 plots are allowed, but program execution will be very slow, and no more than 36 plots are recommended. Crop and tree yield data are usually converted in the output files to a per-ha basis. HyPAR can model up to 50 trees (of 5 species) but there can only be one tree per plot in a

disaggregated canopy. Separate output files are produced for each tree, and tree is allocated a number in the Tree Individuals Editor Sub-Screen (qv).

5.3 Model Options

Two tree light interception models are provided in HyPAR v3.0:

- a **uniform canopy**, where tree foliage is represented as metre-thick layers, each containing a known weight and area of leaves, but which are horizontally homogeneous and
- a **disaggregated canopy**, where the canopy is composed of trees with known co-ordinate positions, and an elliptical crown of known dimensions. In this scenario light is assumed to follow a 'standard-overcast sky' brightness distribution.

Four hydrology models are provided : PARCH, Tipping-Bucket, Brooks-Corey and van-Genuchten. The simplest of the models is 'Tipping-Bucket' which assumes that water in excess of a defined volumetric fraction (field capacity) moves down to the next layer provided that there is room for it. The 'Brooks-Corey' and 'van Genuchten' models assume that water movement is governed by Darcy's law and use different equations to relate soil moisture water content (q), moisture potential (Y) and hydraulic conductivity (k). The PARCH option follows the methods used in the original PARCH model and estimates hydraulic characteristics from soil structure following the Campbell (1985) method.

Depending on the hydrology model selected in the General Screen, four pedotransfer functions are available. These generate the parameters required in equations relating soil moisture potential and content, from more easily measured soil characteristics like texture and bulk density. More information on these choices is given in the Technical Manual. Not all combinations of hydrology model and pedotransfer option are valid with all soil types. If an invalid combination is chosen the program will generate an appropriate warning message and not run.

6. Climate Screen

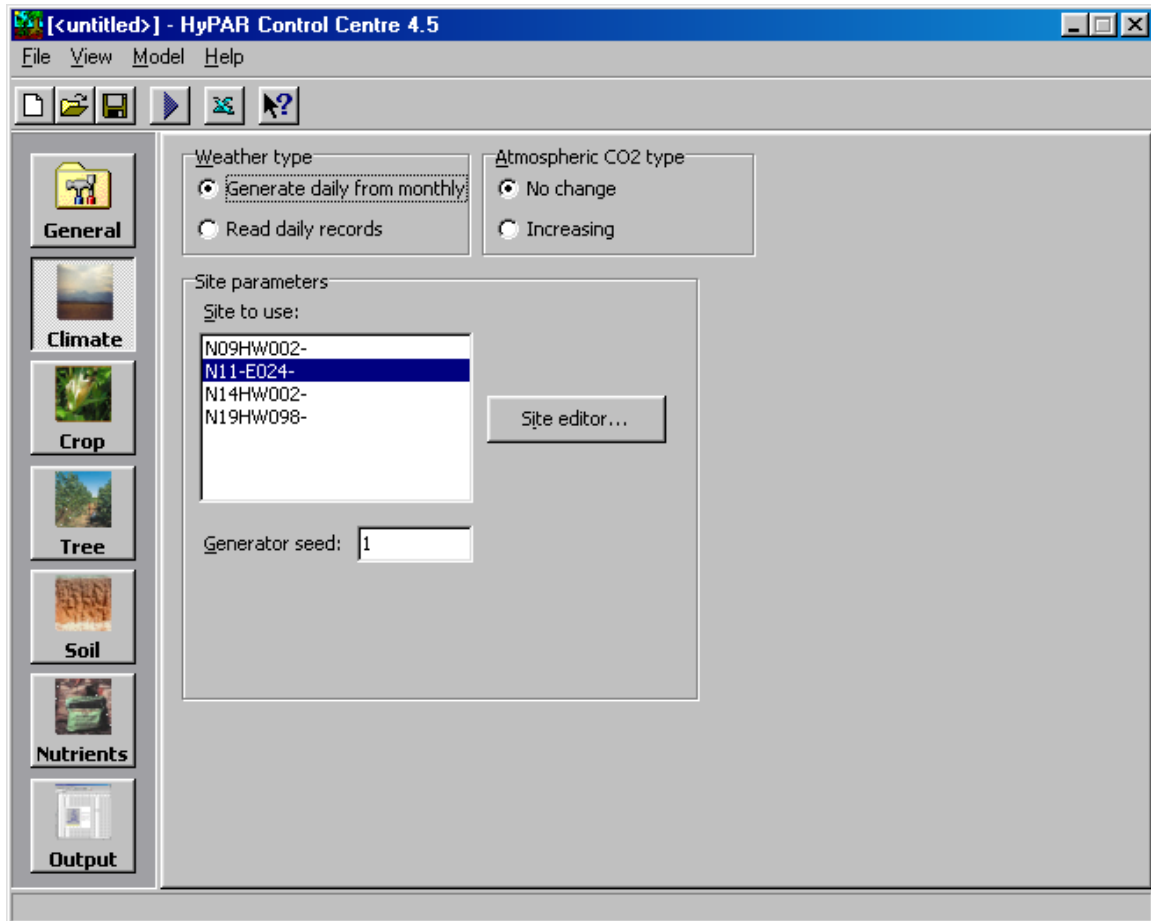


Figure 5. The Climate Screen

The Climate Screen allows the user to provide his/her own daily (or monthly) meteorological data or select monthly data from a climate database to generate daily weather conditions typical of an area of the world specified by latitude and longitude.

6.1 Weather Type

Selecting 'Read daily records' causes the Climate Screen to change (not shown in Figure 5) and ask for a file name and met file format to be specified. These formats are explained in Technical Manual. HyPAR requires a full 365 days of data with no missing records.

Selecting 'Generate Daily from Monthly' takes latitude and longitude information to invoke a worldwide database of monthly meteorology from which it predicts daily weather conditions (Figure 5). A number of these monthly data files are provided with HyPAR. Specific files, or the full set, can be provided on request.

Other weather parameters are:

- generator seed for the weather generator (can be any integer, and if it is unchanged in repeated runs identical daily weather will be used);
- whether atmospheric CO2 is allowed to increase at current rates;

6.2 Climate Site Sub-Screen

The Site Climate Sub-screen (Figure 6) allows the user to edit the monthly meteorological data provided for a site. The filename begins with 'Sxx' or 'Nxx' for xx degrees north or south latitude, and is followed by Exxx or Wxxx to show the longitude. An 'H' after either latitude or longitude indicates a half degree. The last line of the table indicates the % change (-ve or +ve) from the displayed input values which will be applied in the subsequent HyPAR run.

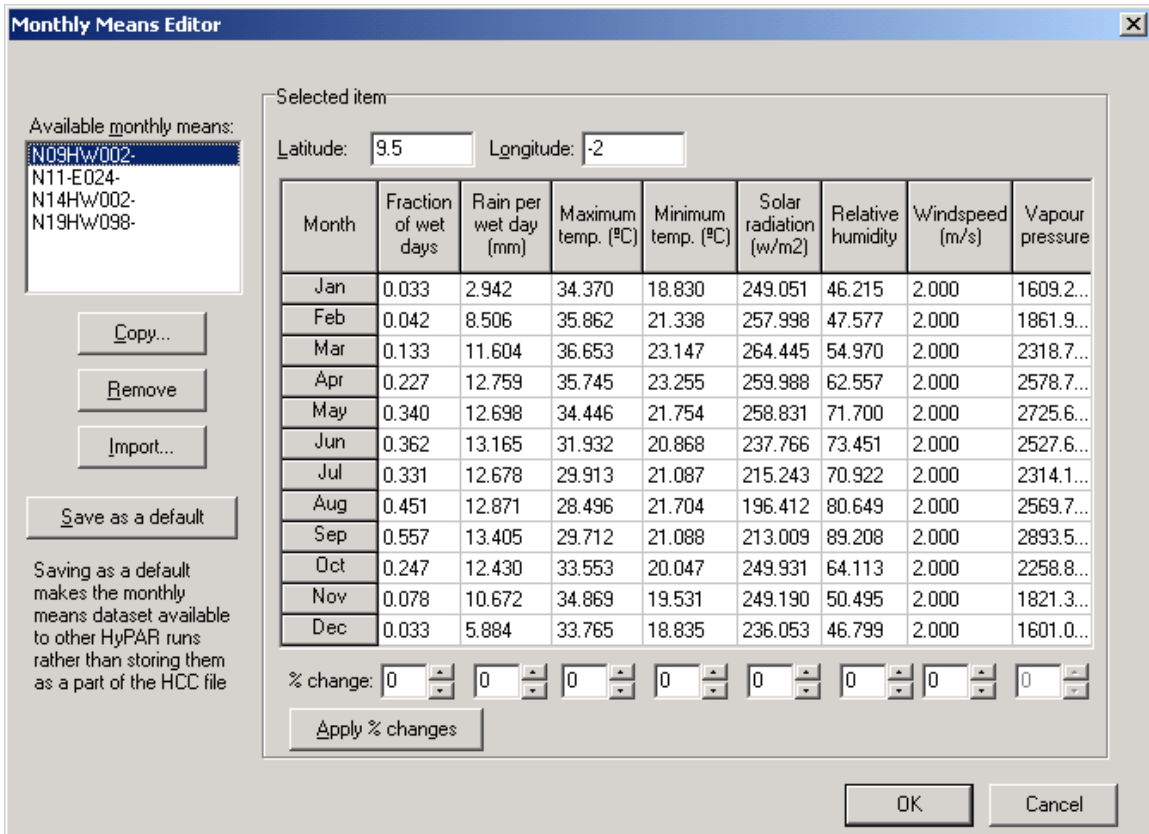


Figure 6. The Climate Site Sub-Screen

7. Crop Screen

The Crop Screen (Figure 7) allows a choice of cultivar parameters, spacing, sowing date and management to be set for one or two crops per year.

An option is provided to exclude the planting of crops, if the user wishes to grow solely trees or indeed to grow nothing at all (for example to examine different drainage scenarios).

HyPAR can be set to simulate different planting densities (in plants per ha). The timing of planting is set in two ways:

- the minimum water content which must be present in the top 40cm of soil is set in the first box,
- the earliest day on which planting can take place is set in the final box

Setting the former to a very low figure can force planting to take place on the date provided.

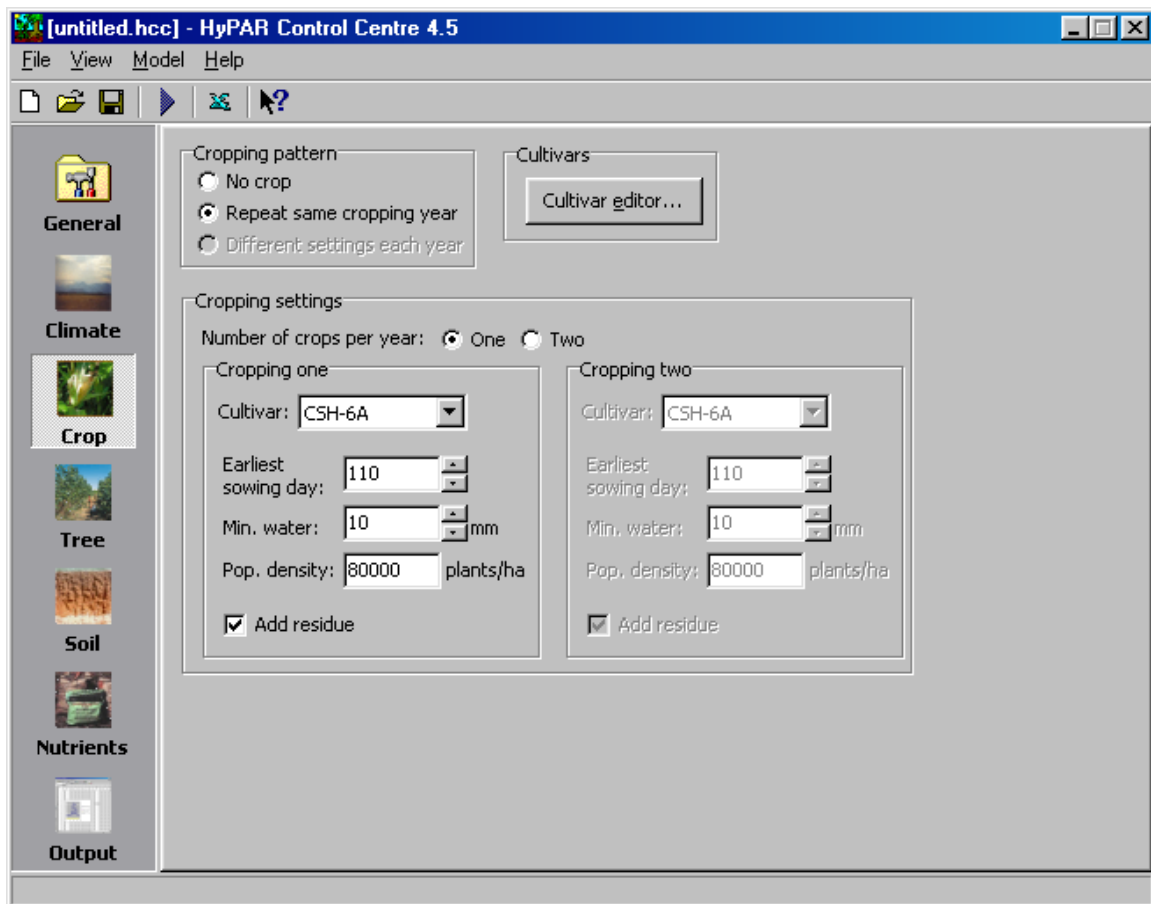


Figure 7. The Crop Screen

If the 'add residues to soil at harvest' is not ticked they are assumed to be removed - e.g. by wind or harvesting, otherwise they are added on the harvest date to the surface fresh organic matter pool (q.v). Residues include crop stalk and leaves, but exclude haulm.

7.1 Cultivar Sub-Screen

By clicking on the 'Cultivar Editor' button, a sub-screen is displayed (Figure 8) which enables existing cultivars to be edited or new ones created (using the Copy, Remove and Import buttons). PARCH was initially designed to simulate the growth of sorghum, and HyPAR is accompanied by files giving information for three cultivars (CSH-6A, CSH-8b and Dk55_e) of sorghum some of whose parameter values are shown in Table 2. Default parameter values for maize (KCBSJL) are also provided. Parameter values can also be saved to the 'default' folder, and will be available to other HyPAR runs. Explanations of the crop parameters are provided in Table 3, with more information in the Technical Manual.

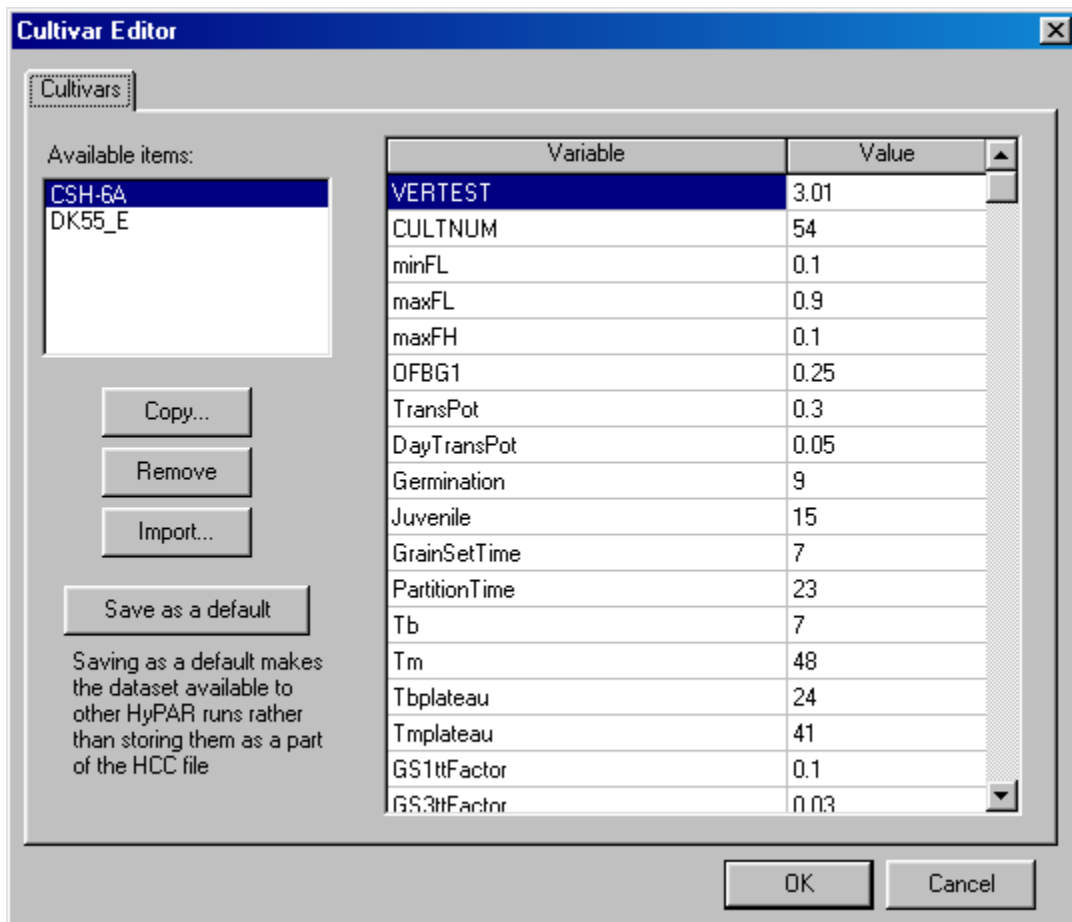


Figure 8. Crop Cultivar Sub-Screen

Variety/ parameter	CSH-1	CSH-6	CSH-8	SPV-351	SPH-280	M-35-1	65D
GS1tt	370	370	370	566	398	365	594
GS2tt	650	650	650	655	579	680	604
GS3tt	640	640	640	615	600	609	702
GNC	32	18	40	22	40	15	26
MaxGW	.033	.033	.041	.029	.041	.042	.040

Table 2 - Typical Parameter Values for 7 sorghum varieties (Time in degree days for the tree crop growth stages - GS1tt, GS2tt, GS3tt), a conversion factor used for grain numbers and the maximum weight of individual grains (g))

Cultnum	Number of entries in the cultivar file and should not be changed.
DayTransPot	Maximum fraction of stem available for translocation which can move each day.
emRDFactor	Factor affecting downward growth of roots at germination.
emRWLFactor	Factor affecting thickness of roots at germination.
FineRoot	Downward roots are this factor thinner than average roots.
Germination	Time, in days, for seed to use carbon supplies.
GNC	Conversion factor for grain number. This is quite variable and needs observational data to quantify it. Maize obviously has fewer but larger grains than sorghum or millet. This factor becomes important in unstressed crops at low population densities, or in crops that are stressed only in Growth Stage 2 (GS2), since grain filling will then limit yield.
GrainSetTime	Time, in days, from anthesis to grain setting.
GS1tt	Growth stage 1 thermal time. Units in day degrees. This can be determined from observations of the time of reaching critical growth stages in relation to recorded temperature.
GS1ttFactor	Reduced thermal time accumulation by stress before anthesis. A value of 0 shows unaffected, while a value of 1 shows large effect.
GS2tt	Growth stage 2 thermal time. Units in day degrees. This can be determined from observations of the time of reaching critical growth stages in relation to recorded temperature. Anthesis, the end point of GS2 is easy to determine by eye. The thermal time requirement for each stage can be calculated from phenological records using the daily temperature records from a meteorological station.

GS3tt	Growth stage 3 thermal time. Units in day degrees. Time from anthesis to harvesting .
GS3ttFactor	Increased maturity rate after anthesis due to stress. Common value is 0.33. Range 0 (unaffected) to 1 (large effect).
Juvenile	Length in days of plant juvenility - characterised by thinner than average roots and leaves.
K	Light extinction coefficient is variable and depends on leaf orientation and spatial distribution. It can be calculated by working back through Beer's Law with a known leaf area index and light interception.
LeafStress	Fraction of leaf area to senesce per day with stress. Range 0 (none) up to 0.25 (big effect).
Lifec	Rate of phenological death. Values less than one indicate faster than average senescence.
Lrollmax	Maximum leaf rolling susceptibility (40%).
Max FH	Maximum fraction of assimilate that can be partitioned to haulm per day in GS3.
MaxFL	Maximum partitioning to leaves in GS1 and GS2.
MaxGW	Maximum grain weight. This is quite variable and needs observational data to quantify it. Maize obviously has fewer but larger grains than sorghum or millet. This factor becomes important in unstressed crops at low population densities, or in crops that are stressed only in Growth Stage 2 (GS2), since grain filling will then limit yield.
MaxPlantArea	Maximum leaf area for an individual plant in a sparse canopy (leaf area per plant metre squared). This controls leaf expansion rate during establishment. The maximum leaf area is used to ensure accurate predictions at low plant densities. The number of tillers is not modelled directly by HyPAR (PARCH model). However, the number of tillers will be important when the plant population density is low. Some plants should be grown at very low densities (that is as single plants) in order to determine the maximum leaf area per plant under stressed conditions with no interplant competition. The default value for MaxPlantArea in most cultivars is 0.5 m ² .
MaxRdepth	Maximum rooting depth, this may be stopped by rock and other hazards.
MaxRstress	Factor to limit the effect of stress on root extension (0=unaffected by stress, 1=full effect of stress).

MaxUptakeRate	Maximum water uptake rate. Units in millimetres per millimetre layer. Range 0.01 to 0.02.
MinFL	Minimum fraction of photosynthate partitioned to leaves in Growth Stages 1 and 2.
Ofbg1	Fraction of carbon allocated to roots before stress adjustment.
PartitionTime	Minimum time for grain filling, this determines the maximum daily gain.
Photosynth1	Conversion efficiency during GS1 and GS2. Units in grams per megajoule. Final yield is very sensitive to this parameter.
Photosynth3	Conversion efficiency during GS3. Units in grams per megajoule. Final yield is very sensitive to this parameter.
PwiltP	Permanent wilt point of plant in metres. Range 1 (very low) to 200 (high).
qD	The adjusted water use efficiency. Transpiration equivalent, kilogram of carbon per kilogram of water transpired per unit SD. This parameter is best left alone.
Rdist	Root distribution 'half-depth' function in millimetres. Range 100 (shallow) to 1000 (deep).
Rdmin	The initial rooting depth, equals the sowing depth (e.g. 20cm)
Recovery	Rate of recovery from stress. Range 0 (instant) up to 1 (very slow)
RLVmax	Maximum root length per unit volume. Units in cm per cubic cm.
<p>Root-parameters The following root parameters determining the rate of root development, the distribution of roots and the maximum root depth are difficult to estimate. Often, little attention is paid to the rooting depth and distribution. Regular checks on rooting depth will help identify the maximum rate of root extension, though only if the crop being grown in a moist, well structured soil with no physical barriers to root growth. Root analysis can also determine the maximum root length per unit volume of soil (RLVMax), the root distribution with depth (RDist) and the genetically determined maximum root depth when there are no restricting soil factors (maxRdepth).</p>	
Rrmax	Maximum daily root extension rate in millimetres.
RstressFBG	Additional fractional below-ground partitioning with stress [0=stress has no effect, (OFBG+RstressFBG) at maximum stress.
RWLfactor	Kilograms of Carbon per centimetre root length.
SLA1	Specific leaf area in Growth Stage 1 (GS1). Units in metres squared per kilogram. This is very important to the correct functioning of the model as it drives the leaf expansion rate with carbohydrate assimilation.

	Although the value may appear to be conservative for a species they are easy to measure and worth checking. Measure the leaf area and weight from the point where they leave the stem, as the leaf wrapped round the stem is not generally a net assimilator.
SLA2	Specific leaf area in Growth Stage 2 (GS2). See SLA1 above.
SLAstress	The effects of stress on Specific Leaf Area, fractional reduction. Range from 0 (none) to 1 (full)
Stindex	The ratio of transpiration demand against available transpiration that will cause maximum stress.
StransReduct	Translocation rate reduced by stress. Range from 0 (unaffected) to 1 (big effect).
Tb	Base temperature determined from Thermal Gradient plate. Units in degrees Celsius. This varies between cultivar and species. For lowland tropical areas, the growth is not generally limited by low temperature and a value of 7-8oC would be appropriate for sorghum and up to 10oC for maize.
Tbplateau	Point where an increase in temperature has no effect on rate of growth. Units in degrees Celsius. This varies between cultivar and species.
Tm	Maximum temperature for growth. Units in degrees Celsius. This varies between cultivar and species.
Tmplateau	Start of thermal denaturation, which induces stress. Units in degrees Celsius.
TransPot	Fraction of stem available for translocation.
Vertest	This is the version number of the cultivar file and should not be changed.

Table 3 - The 50 Crop Parameters used by the PARCH model, and advice on typical values.

7.2 Validation of crop yields

Before considering competition from trees, compare the model predictions of crop yield, and other variables like biomass and maturation time, with those expected for your soil and climate conditions. If none of the predefined cultivars is suitable (only maize and sorghum are currently available) then you will have to calibrate your own cultivar. There are 50 crop parameters used in HyPAR⁷ but many will not need to be changed. Those likely to require special efforts to measure and calibrate are: Tb, Tm, Tbplateau, Tmplateau (temperature response growth parameters)

⁷ 4 additional parameters are provided to be consistent with the original PARCH model, but do not need to be changed.

GS1tt, GS2tt and GS3tt (thermal time to each of the growth stages), SLA1 and SLA2 (specific leaf area - g/m² - of the first 2 growth stages), MaxPlantArea (maximum leaf area of isolated plants), k (light extinction coefficient) , GNC (grain weight to number conversion) and MaxGW (maximum grain weight). Parameters least likely to change are qD, Photosynth1 and Photosynth3.

8. Tree Screen

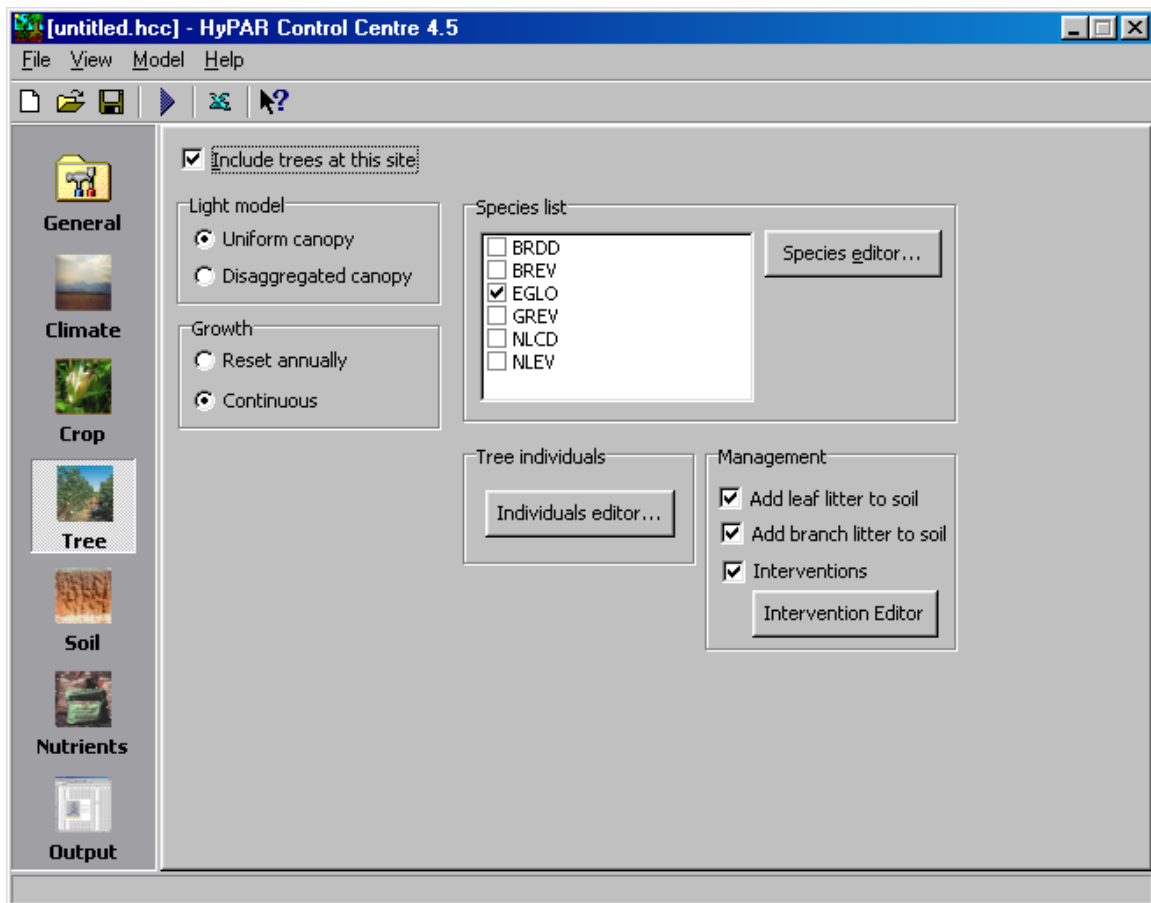


Figure 9. The Tree Screen

The Tree Screen (Figure 9) includes factors such as whether trees are planted, what light model to use, whether they are allowed to grow, what happens to their foliage and branch litter, and a range of management options. If the 'Include trees at this site' checkbox is ticked, trees are included as an overstorey. Selecting the 'Reset Annually' growth option resets leaf area index and all tree-related variables at the end of each 365 day period to the starting conditions set in the Individuals Sub-Screen. This may be desired, for example, if the user wishes to test the

effect of climate on the crop-tree system, whilst maintaining other variables constant. Selecting the 'Continuous' option allows trees to grow for the full length of the run.

Another set of options controls whether leaf or branch litterfall are removed from the site or not. Daily leaf and branch litter can be added to the soil or removed from the site. These switches apply to natural litterfall in addition to a range of pruning, coppicing and thinning options.

Setting the 'Uniform Canopy' option assumes vertical disaggregation of tree-leaves into 1m layers, but no horizontal disaggregation. This is the default option and is significantly faster than the 'Disaggregated Canopy' option, which represents the position and shape of individual trees as described in the following sections. Competition for light, water and nutrients is calculated separately in the plots specified in the General Screen, and output is presented on both a plot and field basis.

8.1 Tree Management Sub-Screen

The Tree Management Options Sub-Screen (Figure 10) allows the user to control how trees are pruned, coppiced or thinned, and what is done with the branch prunings.

The following management options are available:

- no management - where trees grow uninterrupted;
- use same management settings every year - where pruning, coppicing or thinning treatments are imposed each year;
- use individual management settings for each year - different management options can be applied to some years and not others.

To apply management options to the trees, HyPAR requires information about the day(s) of intervention, the management type for that day, and some additional information depending on the type. [If different options are required in different years, use the Add, Copy or Remove buttons to quickly add extra years information based on existing data]

Columns are provided for:

- day for management intervention (note these must be in ascending order).
- remove or keep prunings
- management type (i.e. coppicing, pruning or thinning)
- Additional information (dependent on management type):
 - Pruning - % height for pruning
 - Coppicing - no additional information required

- Thinning - click ellipsis (.) to display a further Sub-Screen (not shown) to allow individual trees to be selected for removal (with the fate of leaf and wood litter determined by 'remove or keep prunings' button).

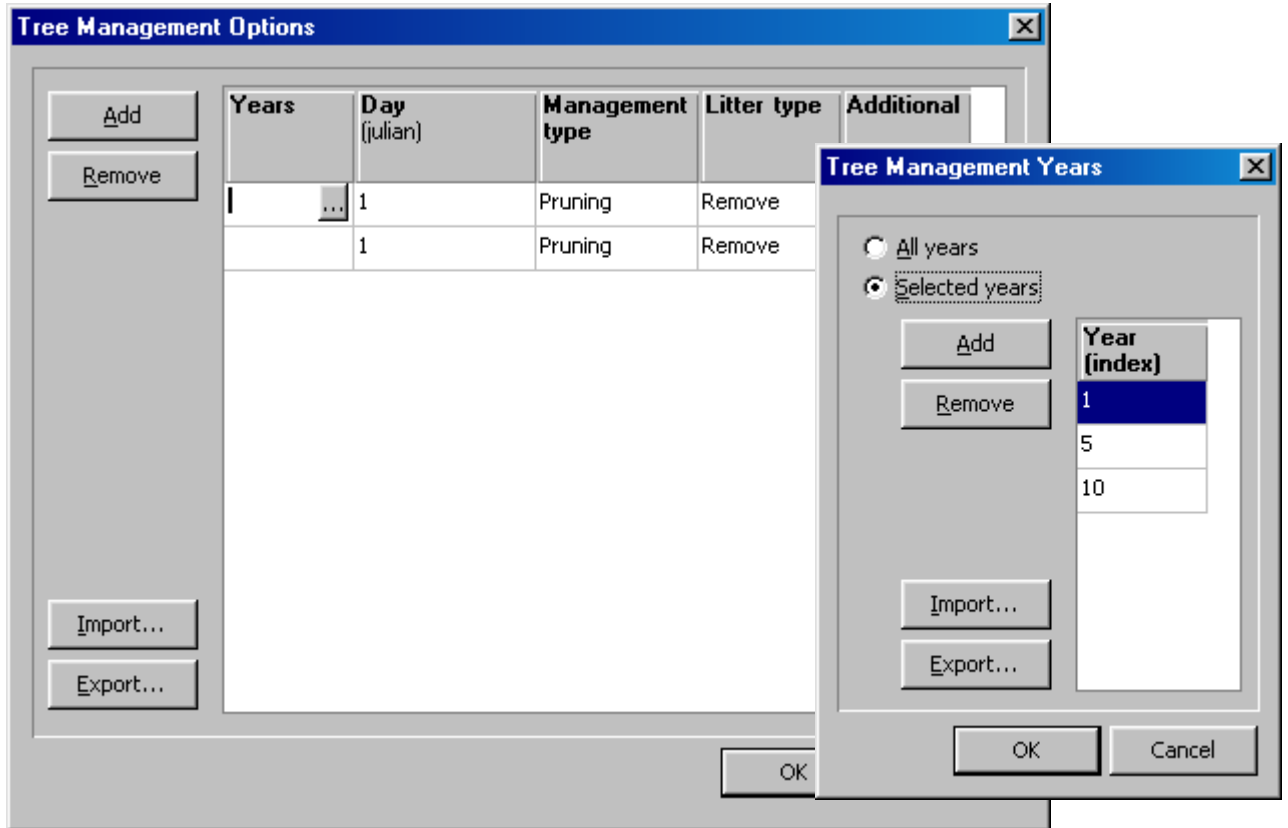


Figure 10. Tree Management Sub-Screen

8.2 Tree Individuals Sub-Screen

The Tree Individuals Sub-Screen enables the user to specify the number of trees, and their species size and location (Figure 11). Variables included are reference-number, species, diameter at breast height (DBH), starting heartwood area, height to base of crown, proportion of N in foliage, and co-ordinate position within the plot (only used if canopy disaggregation is selected).

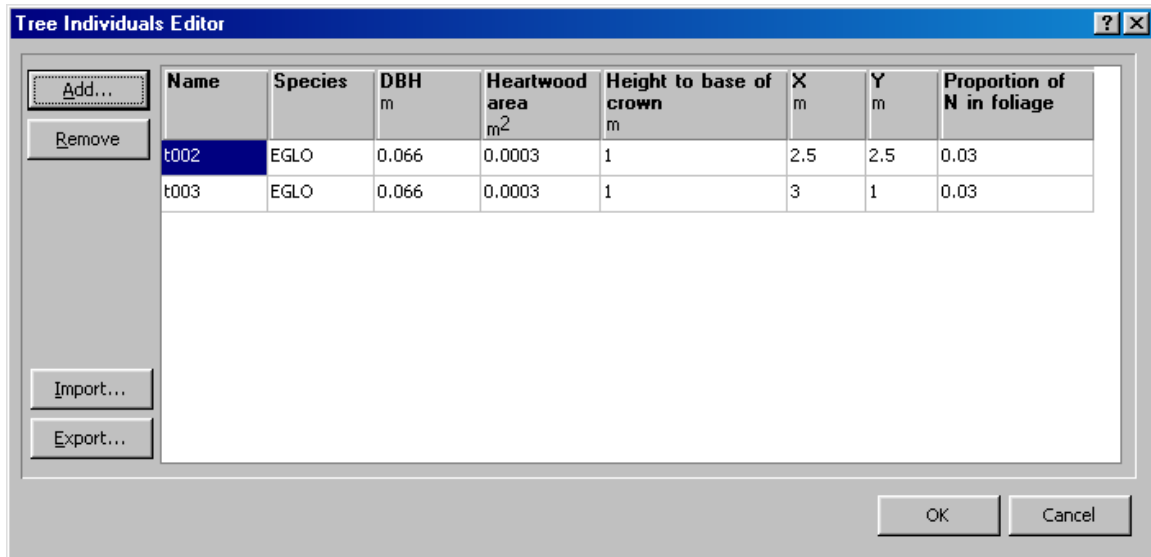


Figure 11. Tree Individuals Sub-Screen

8.3 Tree Species Sub-Screen

This sub-screen allows 38 tree species-specific parameters to be set (Figure 12). They are listed in Table 4, together with advice on typical values. Guidance is provided in choosing appropriate parameter values since many of these are rather physiological in nature and not easy to verify experimentally. Further details on the processes simulated by the tree routines of HyPAR are given in the Technical Manual, and help messages are available by allowing the mouse cursor to hover over a variable name whilst running the programme.

Typical parameter files are provided on the installation disk for 6 idealised tree types: broadleaf evergreen (BREV), broadleaf cold deciduous (BRCD, broadleaf dry deciduous (BRDD), needleleaf evergreen (NLEV), needleleaf cold deciduous (NLCD), needleleaf dry deciduous (NLDD). Additional species files are included for Eucalyptus (EGLO) and Grevillea (GREV). 36 Parameters are available to control the growth of trees and distinguish between different species or idealised types.

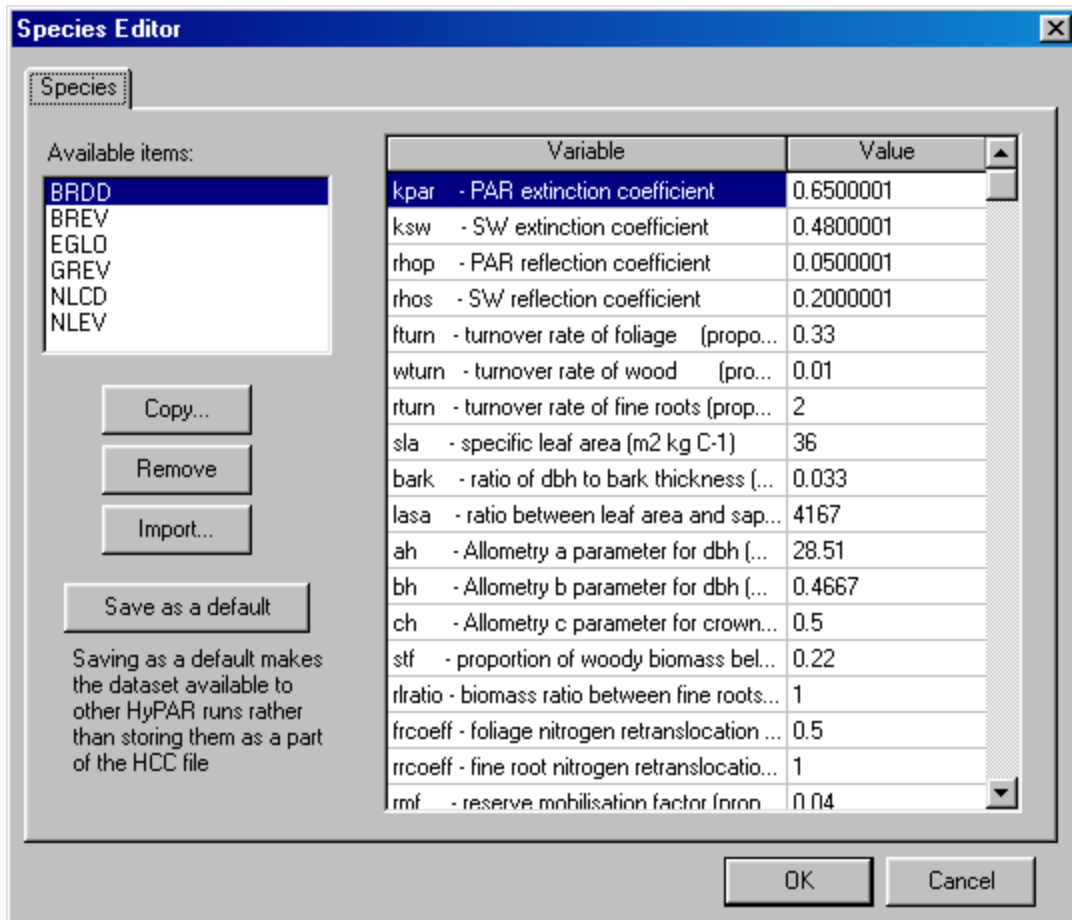


Figure 12. Tree Species Sub-Screen

ah & bh	Allometry parameters relating for dbh D_w (m) to height H_W (m) (see Technical Manual)
bark	Ratio of bark thickness to dbh. Units in $m\ m^{-1}$. By default 'bark' is set to 0.033 for broadleaves & 0.01 for conifers.
ch	Allometry parameter to calculate crown diameter (m) from dbh (m). Only used with disaggregated canopy option.
d_leaf	Leaf characteristic dimension. Units in m. This is usually the longest dimension of an average leaf and is added to the stomatal conductance of individual leaves to calculate the boundary-layer resistance of the whole plot (Section 16.7).
formf	Tree form factor (dimensionless). Higher values of this factor (see Section 16.11.1) indicate more cylindrical tree boles. Lower values imply taller trees for given carbon mass. Default HyPAR values are 0.6 for broadleaves or 0.56 for conifers. Cannell (1984) gives further values.

frcoeff	Foliage nitrogen retention coefficient (proportion). This is the proportion of nitrogen that is not retranslocated from dying leaves before they fall off to join the surface litter pool. This parameter is usually set to 0.5, but will often be a site-specific rather than species-specific value.
frr	Ratio between C:N ratios of foliage and fine roots.
fsr	Ratio between C:N ratios of foliage and sapwood. The C:N ratio of any one tissue varies as a function of nitrogen uptake and loss, but the daily allocation routine optimises the nitrogen pools to ensure that the relative C:N ratios set by fsr and frr, are held relatively constant (Section 16.11.2).
fturn	Turnover rate of foliage. Units are proportion yr ⁻¹ . Leaf longevity may vary from several months to several years. Longevity is often associated with 'specific leaf area', with thicker leaves, or needles, tending to live longer. Note that fturn represents 'routine' foliage turnover associated with ageing. Phenology events like day-degree sums or extremely low water potentials are also included in HyPAR as a cause of leaf loss. Loss of lower canopy layers after long-term negative carbon balance is also additional to the turnover represented in fturn. By default fturn is parameterised at 0.33.
gmin	Cuticular conductance to CO ₂ . Units are in m s ⁻¹ . Users are not encouraged to change this from the default.
Kpar	Photosynthetically active radiation (PAR) extinction coefficient. PAR received by each canopy layer is used in the photosynthesis routine (PGEN). Typical values are 0.5 - 0.8 for broadleaved canopies and 0.4 - 0.6 for coniferous forests.
ksw	Short-wave (SW) extinction coefficient. SW radiation is used in calculating stomatal conductance and canopy energy balance. Foliage absorbs a higher proportion of PAR than SW, so typical values are 0.5 for broadleaves and 0.4 for conifers.
lasa	Ratio between leaf area and sapwood area. Units in m ² m ⁻² . This is a very important ratio since HyPAR runs a 'pipe model' daily to allocate available carbon between carbon between leaves, roots and sapwood storage. Values of lasa are given by Gholz et al (1979) for a range of deciduous species. In reality, the leaf area (or mass) which can be supported by a given sapwood area will depend on xylem resistance, dryness of the soil, and tree height (Landsberg 1986, p37), and will change seasonally. HyPAR currently assumes a single value of 4167 m ² m ⁻² for broadleaves and 3333 for conifers.

live	Proportion of sapwood alive. The proportion of live sapwood controls the size of the carbon store which can be employed to produce new leaves or roots should there be insufficient leaves remaining after drought or pruning events. A high investment in live sapwood confers a species with resilience to recover from stress or management, but is achieved at the expense of higher respiratory losses. This value is set by default as 0.17 in broadleaves and 0.708 in evergreen species. Data is provided by Panshin et al. (1964).
ngr	Maximum leaf conductance to CO ₂ . Units are in m s ⁻¹ . By default, values of 1672 are used for broadleaves and 2223 for evergreen. Users are not advised to change these.
nrc	Proportion of foliage nitrogen bound in chlorophyll.
pruba	Proportion of foliage nitrogen bound in Rubisco. Foliage nitrogen is divided into 3 components: rubisco-bound, chlorophyll-bound and 'other'. This partitioning is important for calculating photosynthesis rates. The 'other' fraction (structural, nuclear and cytoplasmic material) does not increase unless leaf structure increases. Foliage longevity and photosynthetic efficiency are related to this 'other' component (Section 16.2). The ratio of rubisco-N to chlorophyll-N represents the relative investment in light harvesting and dark reaction machinery, and represent shade adaptation in different species.
ptype	Species vegetation type (2=evergreen;3=cold deciduous;4=dry deciduous;5=dry deciduous with delayed regrowth). These codes switch on different phenology routines which control the growth and loss of leaves after different degree-day sums in temperate deciduous trees, or the loss of leaves if soil water potential drops below a minimum threshold (-1.5MPa). The phenology of leaf loss is complicated in many humid tropical, or semi-tropical trees and it may be necessary to add additional ptypes in the future.
rgf	Factor by which net photosynthesis is reduced to allow for growth respiration. By default it is set to 0.75 and should not need to be altered.
rhop	Reflection coefficient of PAR. Typically this is 0.05 in broadleaves and 0.03 in conifers
rhos	Short-wave reflection coefficient. This is much higher than for PAR, being typically 0.2 for broadleaves and 0.11 for conifers.
rlratio	Biomass ratio between fine roots and foliage (kg C kg C ⁻¹). This is an important parameter for which little data exists in the tropics. By default HyPAR assumes rlratio to be 1, but it is likely to be higher in low fertility sites and lower where nutrients are not

	limiting. This parameter should probably be made a function of soil nitrogen levels.
rmf	Reserve mobilisation factor - maximum proportion of total tree carbon which may be extracted per day from reserves. This parameter controls the speed with which leaf and root regrowth can take place after pruning or other damage.
RootdF	Constant of proportionality relating rooting depth to tree height.
RoothD	Factor for root distribution half depth. This is the depth above which half of the fine roots (mass or length) occur, as defined in the exponential equation given in Section 15.4).
Roothw	Factor for root distribution half width. This is the width beyond which half of the fine roots (mass or length) occur, as defined in the exponential equation given in the Technical Manual
RootwF	Constant of proportionality relating rooting width to tree height.
rrcoeff	Fine root nitrogen retention coefficient (proportion). As frcoef, but for fine roots. The bulk of literature evidence suggests that very little retranslocation of nitrogen occurs before root death so this parameter is usually set to 1.
rturn	Turnover rate of fine roots. Units in proportion yr ⁻¹ . This parameter is very important, but poorly measured. By default it is set to 2 for all generalised tree types, indicating that fine-roots are replaced twice per year. It vary considerably between species, and in later versions of HyPAR, should be made responsive to soil moisture and nutrient conditions.
sla	Specific leaf area. Units in m ² kg C ⁻¹ . This parameter is important as a high value (i.e. large thin leaves) will confer competitive advantage in absorbing solar radiation to individual tree species in mixtures. High sla, however, has a greater respiratory and transpiration cost. It is set by default to 36 for broadleaves and 12 for conifers, but should be measured where possible. Atypical, juvenile- or shade-leaves are easiest to collect, but should be avoided.
stf	Proportion of woody biomass below ground. Globally there is a good relationship between the biomass of coarse roots and tree diameter (Sanantonio et al 1977). By default HyPAR assumes stf to be 0.22 for all generalised tree types.
storef	Maximum proportion of live sapwood used as C storage. This parameter is used with 'live' in Eqn. 35 of Section 16.11.1. To calculate the maximum potential size of the sapwood carbon storage compartment.

TreeRWL	Fine root weight per unit length (kg cm ⁻¹). This factor controls the length of root produced for a given mass of photosynthate allocated to roots. Nutrient and water uptake are then related to root length.
wmf	Factor for calculating minimum wood mass increment This is the minimum proportion of available carbon at the end of a day which is used to increment wood diameter before remaining carbon is optimally allocated between foliage, roots and storage. It is assumed to be 0.1 and is unlikely to require altering.
woodd	Mean wood and bark specific gravity. Units in kg C m ⁻³ . Density values for wood are widely available. Fast growing trees tend to have lower specific gravities.
wturn	Turnover rate of wood. Units in proportion yr ⁻¹ . This represents the annual loss of branches or large roots. By default it is parameterised as 0.01.

Table 4 - Tree Parameters used by the HyPAR model, and advice on typical values.

8.4 Validation of Tree Yields

It is difficult to calibrate tree photosynthesis or foliage growth on a short scale, and the best means of calibration is in comparison with repeated measurement of DBH on individual trees. A sensitivity test of the success with which the Hybrid v3.0 model simulated the observed distribution of 21 tree taxa in North America (Knox & Friend unpublished) indicated particular sensitivity to height allometry (ah and bh), wood density (woodd), form factor (formf), below-ground wood proportion (stf), PAR extinction coefficient (Kpar), proportion of live sapwood (live), leaf characteristic dimension (d_leaf), specific leaf area (sla), and leaf area/sapwood area (lasa).

9. Soil Screen

The Soil Screen (Figure 13) enables users to input soil structure and initial water characteristics. The available options will vary depending on the hydrology model selected on the General Screen.

9.1 PARCH Model Soil Screen

When the PARCH model is selected on the General Screen, maximum soil water potential is requested in the Soil Screen (Figure 13) Initial snow pack and snow melt coefficients are unlikely to be used in the tropics(!), but have been retained from Hybrid for potential applications to temperate agroforestry.

The last column is the starting water content (expressed as a volume water percentage) in each layer and is set using a slider - by dragging or by selecting the slider and using the cursor keys to move the percentage 1%.

Information is requested on 'infiltrate', 'crack distance', 'crack rate', 'drain rate' and 'speed':

- ***Infiltrate*** is the relative infiltration rate, varying from 0 to 1. Zero implies no infiltration, and 1 allows unimpeded water flow into the surface layer. This allows compaction and capping to be simulated in a simplistic manner
- ***Crack distance*** defines an exponential function that is used to redistribute water flowing via macropores. The value entered by the user can be thought of as a 'half depth' for the cracks (i.e. the number of cracks has fallen by 50% at this depth) and is usually between 100 and 500mm.
- ***Crack rate*** is a zero to unity crack fraction defining the proportion of rainfall that flows via cracks, and is thereby initially redistributed according to the exponential function, rather than by Darcian flow. Even with the crack fraction set to 1.0 there will still be significant Darcian flow in most soils, as all soil processes occur simultaneously within a small timestep.
- ***Drainage rate*** is related to the saturated conductivity of the lowest layer, this being modified by soil wetness and an arbitrary factor, Drain Rate, which has a value between 0 and 1. A value of 0 assumes an impervious sub-strata, whereas a value of 1 will represent a freely draining sand i.e. the soil when saturated will lose water across its lower boundary at a rate equal to its saturated conductivity.
- ***Speed*** controls the number of time-steps used to infiltrate the surface puddle into the top soil layer. It is best left at 1.

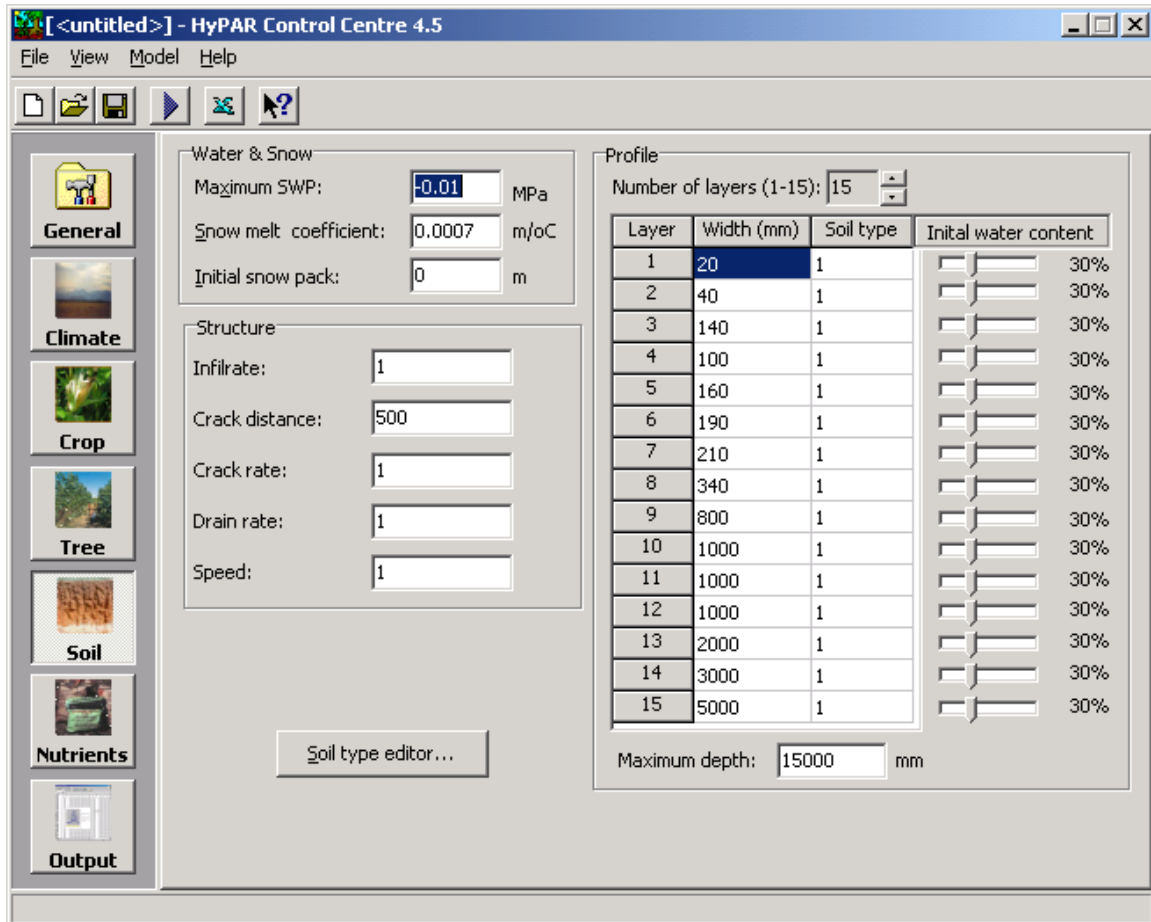


Figure 13 – Soil Screen PARCH Hydrology Model Selected

9.2 Other Models Soil Screen

If one of the other 3 hydrology models is selected an alternative Soil Screen is shown (Figure 14) which asks for the following information:

- **Crack fraction** ($m^2 m^{-2}$) is the maximum fraction of the surface represented by cracks.
- **Crack half-depth** (m) is the depth at which crack volume has diminished by 50%, assuming an exponential decline with depth.
- **Crust factor** is a 0-1 factor to reduce the saturated conductivity of the surface layers
- **Crust depth** indicates the depth of layer with a reduced saturated conductivity
- **Macropore factor** is a 0-1 factor to increase saturated conductivity due to macropores.
- **Macropore depth** is the depth over which macropores increase conductivity.

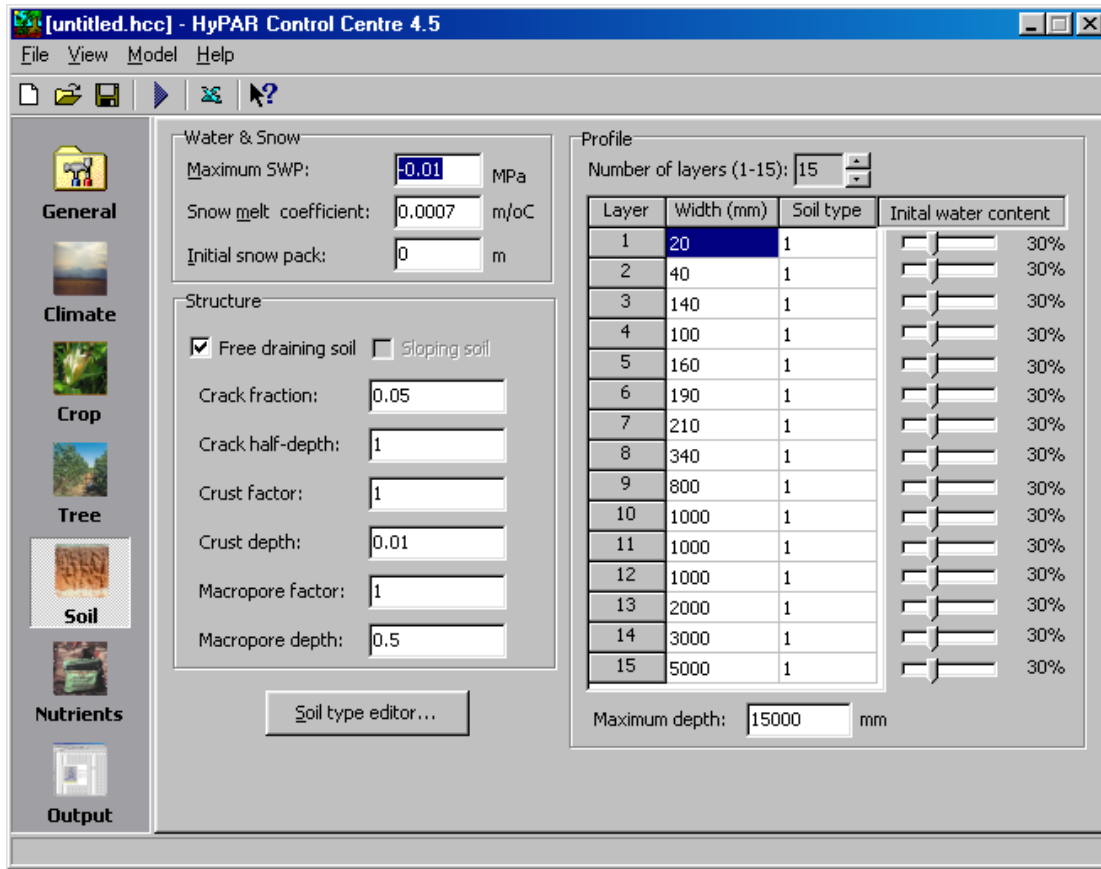


Figure 14- The Soil Screen – non-PARCH hydrology model selected

9.3 Soil Profile

Whichever hydrology model is selected up to 15 different soil layers can be represented. Each layer needs to be given a width (in mm), an initial water content (as a %), and a soil type (defined in the Soil Types sub-menu). The maximum soil depth box is used to calculate the depth of the lowest soil layer and must be filled in.

Adding layers reduces speed at which the model runs. You may find that around seven layers gives a good compromise, with several thin layers (10 - 40mm) near the top, and wide layers (300 - 500 mm) deeper down, where changes in water content occur very slowly. A surface layer of less than 10mm is inadvisable under most circumstances, as the infiltration calculations involved become prohibitively complex, with little increase in modelled accuracy. Conversely, a surface layer thicker than 40mm will increase the speed, but at the expense of reduced accuracy on evaporation, infiltration and establishment calculations.

9.3 Soil Types Sub-Screen

If the detailed hydrological characteristics of a soil are not known they can be estimated from soil texture and bulk density (Figure 15). The following are the minimum values required by the Sub-Screen box:

- Fraction Clay is the fraction of clay sized particles (< 0.002 mm diameter).
- Fraction Silt is the fraction of silt sized particles (0.002 - 0.06mm diameter).
- Fraction Sand is the fraction of sand sized particles (0.06 - 2.0 mm diameter).
- Bulk Density is the dry bulk density of the soil in Mg/m³ (= g/cm³).

If sufficient soil hydrology information is available (and the PARCH hydrology model is selected) the user is able to enter soil hydraulic variables or the parameters required for calculation of the van Genuchten equation directly into an alternative Soil Type Sub-Screen. Information can also be read from a look up table of tropical soils, developed by CEH Wallingford (see HyPAR website)⁸. If all parameters are set to zero they will be estimated internally by HyPAR.

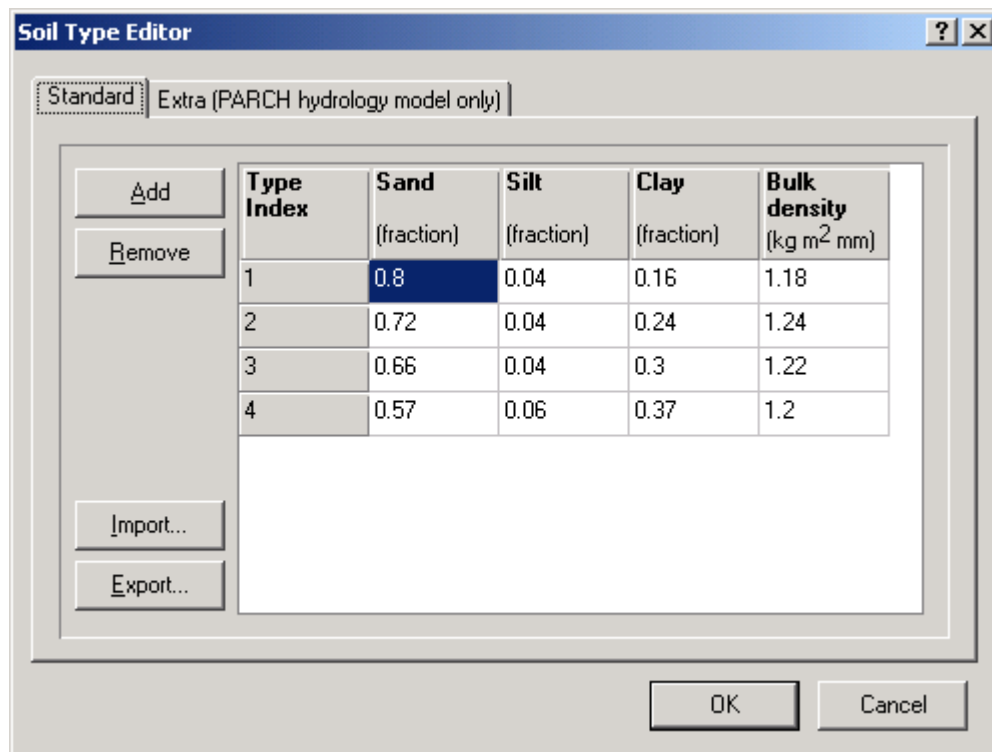


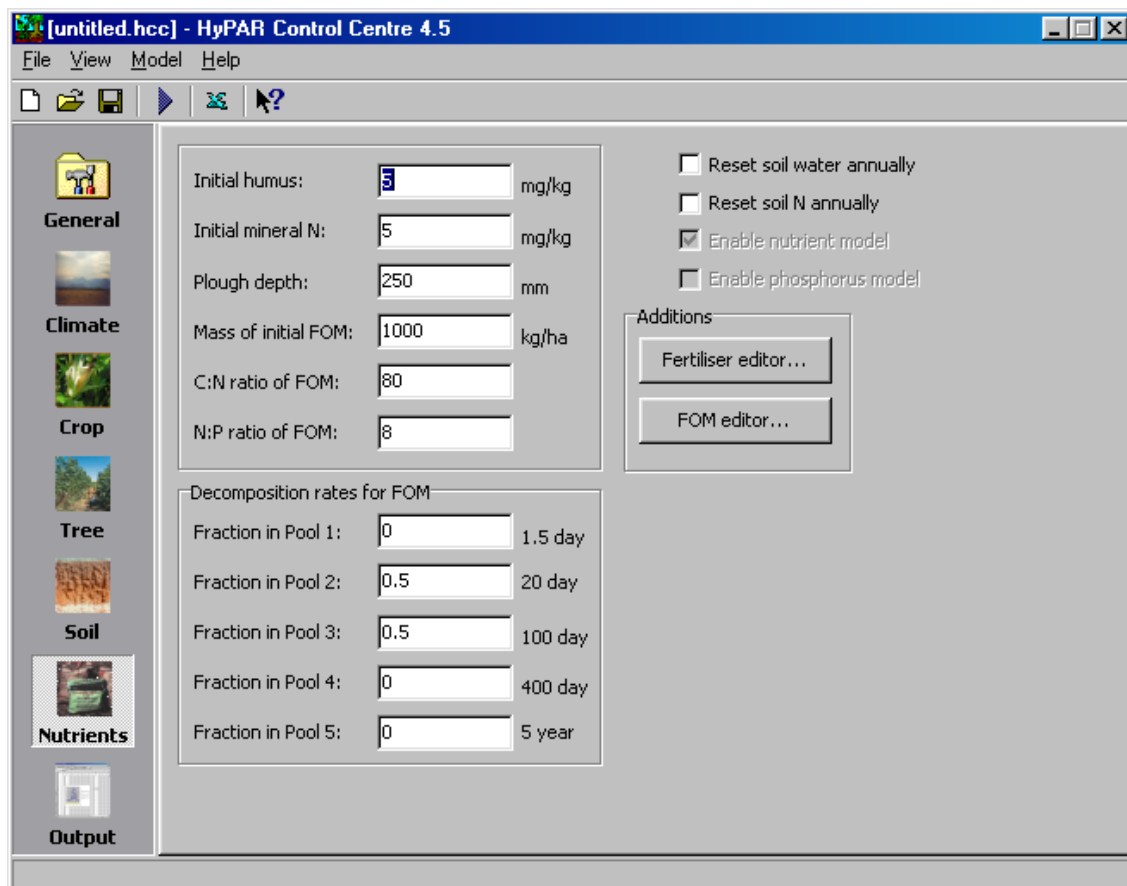
Figure 15 Soil Types Sub-screen (Non PARCH Models Selected)

⁸ Another good model for estimating soil hydraulic characteristics is the SOLPAR model (<http://www.isci.it/tools/>).

9.4 Validation of Soil Hydrology

HyPAR allows you to follow daily water contents in up to 15 depth layers and up to 400 plots within a field. These, and simpler summaries enable the user to calculate a water balance, and to examine the partitioning of water use between transpiration, evaporation and runoff. Ideally water characteristic measurements should be made on the soil to characterise permanent wilting point, field capacity, and saturated conductivity, however these can be derived using appropriate pedotransfer functions from bulk density and clay/sand/silt content in different layers. Starting water content should also be estimated. Comparative measurements of transpiration may be available using sap-flow gauges, stomatal conductance, or eddy co-variance methods. Pan evaporation measurements are frequently available. The selected hydrology model, crack options and pedotransfer function (PTF) make a significant difference to final predictions, and look up tables to aid in the selection of appropriate are expected to be made available soon on the AMP web site.

10. Nutrients Screen



Parameter	Value	Unit
Initial humus:	5	mg/kg
Initial mineral N:	5	mg/kg
Plough depth:	250	mm
Mass of initial FOM:	1000	kg/ha
C:N ratio of FOM:	80	
N:P ratio of FOM:	8	

Pool	Fraction	Decomposition Rate
Pool 1	0	1.5 day
Pool 2	0.5	20 day
Pool 3	0.5	100 day
Pool 4	0	400 day
Pool 5	0	5 year

Figure 16. The Nutrients Screen

The Nutrients Screen (Figure 16) allows users to control which nutrient models are used, whether soil water and nutrient levels are reset annually to starting values, decomposition rates for organic matter, initial nitrogen levels and the potential application of different types of inorganic and organic fertilisers.

Movement of nutrient follows the techniques used in PARCH rather than those in Hybrid. P availability currently has no effect on trees. Inorganic fertilisers and manures can be either ploughed in before planting or added as a top dressing. Soil organic matter is divided into 5 pools, plus humus, and all pools are repeated in each of the modelled soil layers. SOM has a different potential decomposition half-life for each pool. Mineralisation is the total decomposition from the 5 SOM pools, plus humus, limited by temperature, soil moisture and C:N functions. Immobilisation of N takes place if the C:N ratio of fresh organic matter is greater than 20. Uptake of nitrogen by trees and crops is based on their relative root length densities, the amount of available nitrogen in each layer (which in turn depends on soil water content), and the total plant demand.

In HyPAR v3.0 the nitrogen model is enabled and phosphorus disabled.

- Reset soil water annually is used if the user wishes to reset water content in each soil layer back to the starting conditions on the 1st January each year.
- Reset soil N annually is used if the user wishes to reset soil nitrogen pools back to those set in the initial conditions (again on the 1st January).

10.1 Nutrient Initial Conditions

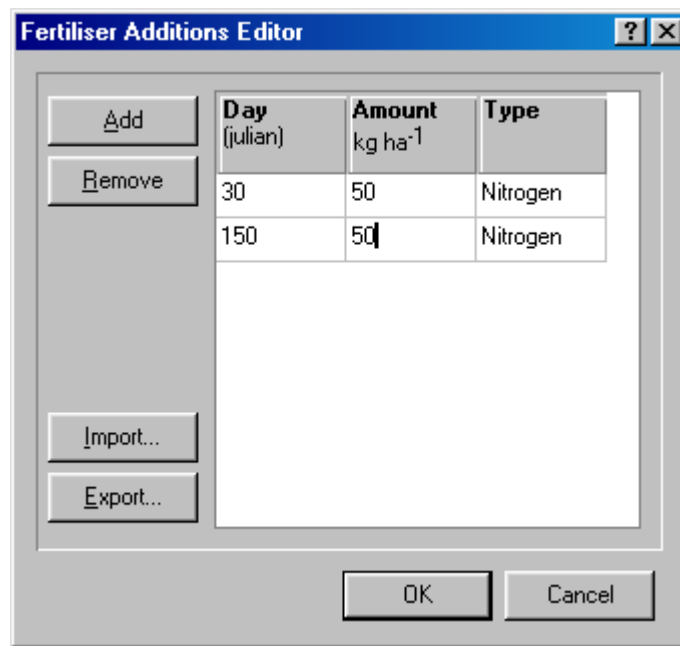
Twelve parameters define the starting nutrient conditions. Initial soil humus, mineral N and fresh organic matter are evenly distributed in the plough-layer and exponentially distributed beneath this (a future version of HyPAR should allow more flexibility)..

- Initial humus (%) is the % (by weight) of soil humus within the plough layer of the soil.
- Initial mineral N (mg/kg) is the concentration (mg/kg or ppm) of mineral nitrogen within the plough layer of the soil.
- Ploughdepth is the depth (mm) of the soil's plough layer.
- Mass of initial FOM (kg/ha) Fresh organic matter, i.e. dead roots etc. in the total profile.
- C:N ratio of FOM - carbon to nitrogen ratio of fresh organic matter
- N:P ratio of FOM - nitrogen to phosphorus ratio of fresh organic matter

10.2 Fertiliser Editor Sub-Screen

Clicking the Fertiliser Editor button displays a Sub-Screen (Figure 17) which allows inorganic fertilisation of N to be simulated. Each row represents a single fertiliser addition. It currently assumes that the same fertiliser applications are made each year.

- **Amount** (kg/ha) specify the amount of fertiliser to be applied (this is kg/ha N or P₂O₅)
- **Fert Type** denotes whether the fertiliser is nitrogen or superphosphate fertiliser (only N is currently applicable in HyPAR v3.0).



Day (julian)	Amount kg ha ⁻¹	Type
30	50	Nitrogen
150	50	Nitrogen

Figure 17. - Fertiliser Editor Sub-Screen

10.3 FOM Editor

The Fresh Organic Matter Sub-Screen enables up to 15 additions, at any time of year, provided that the same additions are made each year. Furthermore, the user can specify the initial amounts of organic matter. Initial organic matter and humus are treated in the same way - i.e. evenly distributed in the plough layer, and exponentially declining below this (Figure 18).

The following parameters are specified:

- Date (Julian Day from the 1st of January - see lookup table in Section 21). The year-day of organic matter addition. Fresh OM (FOM kg/ha). This is simply the dry-weight of fresh organic matter added on each occasion.

- C:N ratio is the C:N ratio of added organic material. Typical values are given in Section 15 but might be 80 for crop residues or 20 for animal manure.
- Fraction in pools 1-5. The model assumes that organic matter is composed of material that decomposes at different rates. To simulate this the model divides the material into a maximum of 5 pools, which have different rates of decomposition. Full details of this procedure are again Section 15.3. For most situations the two extreme pools (1 and 5 will not be needed).

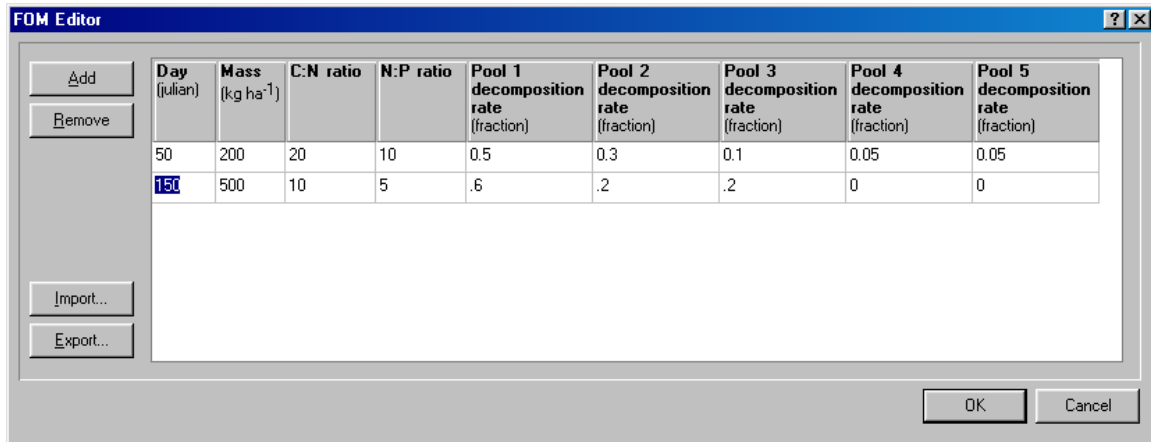


Figure 18. Fresh Organic Matter Sub-Screen

10.4 Validation of Soil Nutrients

Nutrient flows are more difficult to validate, and require measurements of the distribution in the profile of nitrate and nitrogen in the different organic matter pools, and in leachate. Field techniques for these measurements are described in TSBF Manuals⁹

11. Output Screen

The results from HyPAR are presented as a series of comma separated variable (csv) files. These files are designed to be read into a spreadsheet package, such as Microsoft Excel.

Writing output files during a simulation run slows down the program, and printing all possible output variables uses up disk space. The HyPAR user interface therefore allows the user to select and limit the type of output created. There are four output file categories - Environment, Crop, Tree, and Soil. Each of these has three options specifying the time step - Daily, Annual and Summary. Daily outputs are stored as one row per day; annual as one row per year, and summary as the average over the whole run. The latter file is particularly useful because climate

⁹ <http://tsbf.org/homepage.html> (Tropical Soils Biology and Fertility Programme).

variation makes it often preferable to present 20 or 30 year averages of crop yields etc. A global interval can be set for all daily files which prints out data every 'x' days. Full details of the files and variables provided are contained in the Technical Manual.

Environment files: Three file types are produced- daily (envm0000.csv), annual (envmann.csv), and summary (envmsum.csv).

Crop files: if the 'disaggregated' tree canopy is selected then individual daily and annual crop output files can be produced for each plot within the field. Daily (crop0000.csv), annual (cropann1.csv) and summary (cropsum.csv) files can also be produced for the field as an average of all plots, or for the field as a whole if the uniform canopy option is selected.

Tree files: some of the tree output files are for individual trees (tree*.csv), and others for the field as a whole (site*.csv). Again, daily, annual and summary files are produced.

Soil files: field scale soil files are the average of all plots on a daily (soil*0000.csv), annual (soilann.csv) and summary (soilsum.csv) basis. Variables are repeated for each layer in the profile. Individual files can also be requested for individual soil columns under each plot (but take care because this can generate a massive amount of output).

12. Interventions

Interventions are included in most of the tabs. Thus:

- The **Climate Screen** allows the choice of recorded daily weather or predicted daily values from a database of world monthly climate statistics. If the latter is selected, up to 8 generated climate variables may be altered in repeat runs to test the sensitivity of predictions to climate change. CO2 levels can also be altered.
- The **Crop Screen** allows choice of whether crops are planted and whether residues are added at harvest or not.
- The **Tree Screen** allows a choice of whether trees are included, and whether they should be held artificially at a constant annual leaf area index or allowed to grow. It also offers a choice of whether leaf litter is removed from the site and pruning, coppicing and thinning options
- The **Soil Screen** principally allows the user to specify the local soil conditions, but he/she could manipulate the structural and drainage characteristics to simulate the effect of cultivation, tree-roots or organic matter additions.
- The **Nutrients Screen** currently has the nitrogen model switched on and phosphorus off, it allows soil-water and nutrient levels to be continually reset to starting

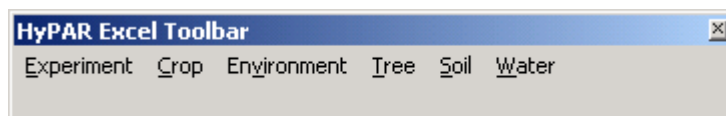
conditions at the end of each year or to change with successive years. Additions of fertiliser and fresh-organic matter are permitted on selected days of the year.

HyPAR calculates rainfall infiltration with a variable timestep which can be as short as one minute, rain which cannot be accepted by the soil remains in a 'puddle' till the next timestep. At the end of the day 'run-off' is calculated, but, if the disaggregated canopy version is selected, this is assumed to equal 'run-on' and is not removed from any of the plots, or the field as a whole. The undisaggregated version (which has one plot equal in size to the field) allows a sloping field to be specified, in which case any water in the puddle above 2mm is removed at the end of the day. It would not be difficult to simulate run-off between plots on a sloping field, but this is not included in HyPAR 4.0, largely to hold the complexity of the input files in check.

Multiple runs of the model can be undertaken to test its sensitivity to a range of parameter values, moving the output files to a new directory after each run. However, if the user wishes to do a large number of such runs, he/she is advised to use HyPAR outside the Control Centre using DOS Batch Files, and make direct edits to the input files.

13. Excel Graphics Macros

Once a run has taken place users should press the Excel Symbol on the main tool bar. This launches a Macro which creates the following window



The first step is to link a folder to an Excel workbook. Click on 'Experiment' and select the folder containing the .csv files that you wish to graph. Then select one of the Crop, Environment, Tree, Soil or Water menus, and follow the choices provided. The selection of graphs provided is currently (November 2001) rather small: please note additional graphs you'd like to see and let us know.

14. Tutorial Exercises

These are under development. We recommend (a) running with the default conditions (select output files in

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