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**A guide to PROMODXL (vsn 1.0) –
a spreadsheet interface to PROMOD**

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Summary

PROMODXL is a Microsoft Excel-based user-friendly interface to PROMOD, a process-based model predicting site productivity. There is some structure to the input spreadsheets, yet they are flexible enough to facilitate easy modification of site factors, default parameter values and run-time options. Normal spreadsheet operations can be combined with PROMODXL. This manual provides a guide to the use of PROMODXL. This interface replaces earlier Excel-based implementations of PROMOD.

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A Guide to PROMODXL

PROMODXL is a user-friendly interface to PROMOD, a process-based model that predicts potential site productivity. The interface is a MicroSoft Excel workbook, and comprises spreadsheets that supply all input data required by PROMOD and to which results are written, an Excel add-in containing the code for the PROMODXL interface and the PROMOD model, and an Excel workbook forming a simple help system.

Some structure is imposed on the input spreadsheets, but these facilitate easy modification of site and climatic data, default parameter values and run-time options. Added flexibility is obtained by combining normal spreadsheet operations and graphing with PROMODXL.

1. What is PROMOD?

PROMOD is a process-based, site-productivity model that predicts the expected productive capacity of a site. It is intended primarily for screening prospective plantation sites but has found a range of other applications. Development of PROMOD was described in Battaglia and Sands (1997), and applications are summarised in Sands et al. (2000).

1.1 What does PROMOD do?

PROMOD predicts the closed-canopy leaf area index (LAI) of a stand and estimates the annual net primary production (NPP) and water use by the stand. It uses a calibration relationship to convert the predicted NPP into a practical measure of the expected productive capacity of the site. It can be combined with an empirical projection model to predict stand development. PROMOD can be used to estimate the variability of annual production under some circumstances.

PROMOD is not a dynamic growth model. It does not predict biomass partitioning, the time-course of stand growth and development (except in conjunction with an empirical stand growth model), or what happens when a stand has a partially closed canopy, or following thinning or pruning.

1.2 What input data are required?

PROMOD requires the site latitude, the maximum amount of water the soil can store down to the rooting depth, a nutrient rating that characterises the capacity of the site to provide nutrients for growth, the depth of any watertable that might increase water supply, and factors such as waterlogging and salinity that impede growth.

PROMOD requires monthly mean daily maximum and minimum temperatures, solar radiation, rainfall, open-pan evaporation, and rainy days per month. Alternatively, it can use observed daily maximum and minimum temperatures, solar radiation, rainfall and open-pan evaporation

1.3 How does it work?

PROMOD uses simple descriptors of soil and climate at a site to calculate the LAI and NPP of a stand around and following the time of canopy closure. It then converts NPP to a practical measure of stem wood production using an empirically derived calibration relationship. PROMOD assumes the stand is in steady-state growth with the canopy closed and the roots fully occupying the soil volume. Several runs are made for each site, depending on how rainy days are distributed in a month, and the presence or absence of a watertable, and results are averaged over each run.

Fig. 1 illustrates the structure of PROMOD and how the input site and climatic factors interact with the processes embodied in the model.

1.4 For which species are PROMOD parameterised?

PROMOD was developed so it can be adapted to a range of species simply by specifying parameters that characterise the physiology of the species, and how the species responds to site factors and environmental conditions. NPP and water use are calculated in the same way for each species, but the calibration relationships converting NPP into a practical measure of productivity may differ.

Parameter sets are now available for the plantation species most commonly deployed in temperate regions of Australia: *Eucalyptus globulus*, *E. nitens* and *Pinus radiata*. Fig. 2 illustrates the quality of predictions obtained for these species.

2. Some PROMODXL basics

The PROMODXL interface comprises several classes of spreadsheet for input and output of data, a simple menu system, toolbar and hot-keys for running PROMOD, editing PROMOD options, and for accessing help, and an Excel workbook-based help system. All calculations are done through VB coded macros. However, normal spread sheet operations and graphing facilities can be used to great advantage.

The interface is provided as source code in the workbook **ProModXL.xls** (which is saved as the Excel add-in **ProModXL.xla** during the installation process), the help workbook **ProModXL.help.xls**, and a sample of fully operational PROMODXL worksheets in **ProModXL.data.xls**.

2.1 Menus, toolbars and hot-keys

The interface makes use of a simple drop-down menu, toolbar and hot-keys. Their actions are summarised in Table 1. These are loaded when the PROMODXL add-in or program is loaded, and are optionally removed when a PROMODXL workbook is closed.

2.2 PROMODXL help system

PROMODXL allows interactive access to a help system based on Excel spreadsheets contained in the workbook **ProModXL.help.xls**. Access to this system is through either the ProMod|Help menu, or the Help button on the PROMOD toolbar, or the PROMOD help key (F12).

The ProMod|Help menu provides access to all help topics (via a submenu ProMod), and to various explanatory tables of PROMOD parameters, and input and output variables (via the submenus Parameters, Input, etc). The Help button and the F12 key both open the help system at a work sheet relevant to the active sheet. When the help workbook is open, you can browse it like any other workbook, or through the hotlinks provided. Pressing ESC will close the help workbook and return to the original active sheet and workbook.

2.3 Spreadsheet classes

Input and output in PROMODXL uses the classes of spreadsheet summarised in Table 2 and described in more detail later. Some spreadsheets are purely a source of data, and some are executable – in the sense that they also control how PROMOD is used, and have data written to them.

Examples of each spreadsheet class are included in **ProModXL.data.xls**. In general, you can edit data on these examples and use them as-is. However, if you want to create a new PROMODXL workbook, base it on a copy of **ProModXL.data.xls** because that workbook contains macros needed to load and unload the PROMODXL add-in.

2.4 About keywords and names

Keywords are used in PROMODXL to locate items of data, the top-left corner of data blocks, or where output is to be placed. For example, to read the name of a species, the spreadsheet is searched

for a cell containing the keywords ***Species name***, and the name is then in the cell to the right of the keyword. In PROMODXL keywords are neither case- nor format-sensitive, but in this manual keywords are displayed in bold italic Arial font, e.g. ***Species name***.

Input and output variables are identified by the names listed in Table 3 and Table 4, respectively.

2.5 About data tables and header rows

All site and climatic data, and all output generated by running PROMOD, are displayed in tables on PROMODXL worksheets. Each row of these tables contains data for a single site, with the site name in Column A. These tables are headed by and identified by a *header row*.

The *header row* names site or soil data to be read and output variables to be produced, locates where on the worksheet the data table is located, and acts as a heading for the input and output data. The header row is identified by the keywords ***Site name*** on *Site data*, *Climate data*, *Monthly PROMOD* sheets, and by ***Date*** on *Daily PROMOD* sheets. The keywords must be in Column A.

The names of input variables are placed in cells immediately to the right of the header-row keyword. Then comes a blank cell, and then names of output variables, again terminated by a blank cell. When the sheet in question is processed an error message is given if an input variable is not recognised, and unrecognised output variables are indicated in the resulting output by “???”.

There can be one or more blank rows between the header row and the body of the table. The body of the table has one row for each site. The names of sites to be processed, or for which data in that row applies, appear beneath the ***Site name*** keyword in column A. The values of the input variables are placed below the corresponding input names, and output will be written below the corresponding output names.

When PROMODXL “runs” a worksheet the header row is located, the names of the input and output variables are extracted, and the first site is name located. Processing of sites commences with this site and proceeds downwards to a blank cell in column A. If a cell containing only spaces or a “-” is encountered in lieu of a site name, that row is skipped. If a cell containing only spaces or a “-” is encountered in the list of output variables, the corresponding column of output is left blank. This allows some degree of formatting of input and output tables.

A PROMOD worksheet can have only one header row. If two or more cells contain the keywords Site name, only the first one is detected and hence only its sites are processed.

2.6 About parameters

When PROMODXL reads data from a *Daily* or *Monthly PROMOD sheet* it assigns default values to the PROMOD parameters appropriate to the species selected for that run. Parameter names, and their meaning and default values, are listed in Table 5.

The default values can then be changed by using the optional keyword ***Parameter updates*** to locate a *parameter update block* which specifies changes to PROMOD parameters that only apply when this sheet is active. Cells below the keyword contain the parameter names, and a blank cell terminates reading parameter names. The cell to the right of a name contains the value of the named parameter.

2.7 About run-time options

Monthly PROMOD runs are controlled by various *run-time options*. These options are described in detail in Sec. 11 and summarised in Table 6. Their default settings normally suffice.

The most important option is how rainy days are distributed in a month. In general, the productivity of a site is calculated by averaging results obtained by applying PROMOD with two or more distinct distributions of rainy days in each month. The default is to use two distributions: rainy days clumped at the beginning of the month, and rainy days distributed uniformly in the month.

Another option controls if the results of the separate runs for each site are displayed, or if only results averaged over these runs are displayed. By default, output for separate runs is not shown.

2.8 Formatting conventions in the example PROMOD work sheets

Formatting of the sample sheets in **ProModXL.data.xls** (i.e. text font and colour, and cell background colour) is purely for explanatory purposes. The conventions are

- the class of a sheet is determined by a red keyword in its top-left corner;
- dark blue text are keywords that determine the nature of associated data;
- brown text are input values you can edit;
- light green background indicates blocks of mandatory input data;
- brown background indicates optional input data;
- light blue background indicates output data.

3. PROMOD site and soil input data

The minimum site and soil data required to run PROMOD are:

- The site latitude
- The site drainage class, indicating if the site is subject to waterlogging or not
- The nutrient rating, expressing the ability of the site to supply the nutrients required for growth
- The maximum amount of water that can be stored in the soil profile down to the root depth.

Optional items are

- The salinity of the soil
- Details of any watertable present
- The minimum amount of water allowed in the soil profile
- Observed values for the closed canopy LAI and peak MAI, or other measure of productivity
- Climate data modifiers used to perform sensitivity analyses with respect to climate.

Site and soil data recognised by PROMOD are summarised in Table 3. Not all items listed in Table 3 are required for each run, as site data can be specified in numerous ways, at various levels of detail. If some input is not assigned a value, then the corresponding site factor is treated in a default manner, depending on the factor. The subsections below show how site data are specified.

You can have as many site data sheets in a workbook as you like, but each can specify input data in only one way. Which site data sheet is to be used is indicated on the *Monthly PROMOD sheet*.

3.1 Nutrient rating

The soil nutrient rating can be specified by values for either **soilNO3**, **nutRating** or **nutClass**. If a value for more than one of these is given for a site, the precedence order is **soilNO3**, then **nutRating** and lastly **nutClass**. Values for **soilNO3** or **nutClass** are converted into an equivalent **nutRating**, which can be output as part of the site input data summary (Sec. 9). The three factors are:

- **soilNO3** is the nitrate concentration ($[\text{NO}_3]$, mg g^{-1}) in soil solution, which has been shown to be a good determinant of canopy LAI on sites that are nitrate limited. Specifying a value for this factor overrides values specified for **nutRating** or **nutClass**.
- **nutRating** is a general way to specify the ability of a site to provide nutrients required for growth. It takes values in the range 0 to 1 where 0 is “concrete” and 1 is the absence of any nutrient limitation. Specifying a value for this factor overrides any value specified for **nutClass**.
- **nutClass** is available for back-wards compatibility with earlier versions of PROMOD. It takes values from 0 to 4, where 0 is the absence of any nutrient limitation.

3.2 Soil water holding capacity

The amount of water the soil profile can hold down to the root depth is **maxASW** (cm) and can be specified in the three ways.

a) Directly

maxASW can be specified directly as part of the site input data. Specifying a value for **maxASW** in this way will override data described in (b) and (c) below.

b) Using rooting depth and soil water capacity

maxASW can be specified indirectly by giving values of the depth to which roots penetrate the soil (**rootDepth**, cm) and the intrinsic soil water holding capacity of the soil (**soilWaterCap**, mm m⁻¹). Use of these two factors will override any other data that potentially specifies this factor, except the direct specification of **maxASW**.

c) Using detailed soil profile data

maxASW can be specified indirectly by detailing the properties of the A and B soil profile and any hard pan between the A and B profiles. A pan reduces root growth and access to water in the B profile. The factors required are detailed in Table 3. The B profile and the pan are optional. Soil texture determines the intrinsic capacity of the soil to hold water, with a texture of 1 holding 170 mm water per m of depth, down to 110 mm m⁻¹ for a texture of 4.

3.3 Waterlogging

The susceptibility of a site to waterlogging is expressed by the **drainage** rating. This is 1 if the site is subject to water logging, and 0 otherwise. By default, **drainage** = 0. Soil is deemed to be waterlogged if (a) the site is subject to waterlogging, and (b) the relative available soil water exceeds a threshold w_{wl} . If the site is waterlogged, photosynthetic production and transpiration are both reduced by the factor a_{wl} . w_{wl} and a_{wl} are parameters of PROMOD.

3.4 Salinity

The salinity of a site is specified by **soilSalt**, the conductivity (mS m⁻¹) of a 1:5 soil solution from a depth of 1.5 m or the bottom of the profile. Salinity reduces photosynthetic production by reducing the ability of the trees to transpire water. The strength of this effect is measured by the PROMOD parameter S_{50} (mS m⁻¹) which is the salinity at which transpiration is reduced by 50%.

3.5 Watertable access

Three factors determine the effects of a watertable: the rotation length (**rotation**, yr), the depth to the watertable (**wtblDepth**, cm), and the salinity of the watertable (**wtblSalt**, mS m⁻¹). If **rotation** is absent or 0, or if **wtblDepth** is absent or greater than the depth of the soil profile or the rooting depth, which ever was specified, the watertable is ignored.

The effect of access to a watertable is modelled through a naïve, speculative and untested device. Productivity over a rotation is assumed to be a weighted average of productivity predicted with and without access to the watertable. The weights are proportional to the fractions of the rotation during which the trees do, or do not, have access to the watertable. The time taken to access the watertable is calculated from an assumed downward root extension rate and depth to the watertable. Daily root extension rate (**rootExtnRate**) is a PROMOD parameter, and annual root extension is the sum of daily root extension over days when waterlogging does *not* occur. When trees have access to a watertable, PROMOD also estimates water drawn from the soil profile and from the watertable.

3.6 *Minimum available soil water*

A non-zero minimum (*minASW*, cm) for the amount of water allowed in the soil profile can be specified. If the available soil water falls below *minASW*, it is assumed the deficit is made up by a supplemental source, e.g. irrigation. This is a useful way to simulate irrigation or watertable access.

4. PROMOD climatic data

PROMOD can be run using long-term monthly mean climatic data, actual monthly climatic data over any number of years, or observed daily meteorological data for any number of days.

The monthly data required are values of the following

- mean maximum temperatures (°C)
- mean minimum temperatures (°C)
- mean total solar radiation (MJ m⁻² day⁻¹)
- total monthly rainfall (mm month⁻¹)
- mean open pan evaporation (mm day⁻¹)
- total rain-days (days month⁻¹)
- total monthly applied irrigation (mm month⁻¹)
- frequency of irrigation (days month⁻¹)

Irrigation data are optional. Monthly climatic data are given on *Climate data sheets* (Sec. 10).

The daily data are observed values of the items listed in Table 7b, and are specified as part of the input on *Daily PROMOD sheets* (Sec. 8).

5. Monthly PROMOD runs

5.1 *What does a Monthly PROMOD run do?*

A *Monthly PROMOD run* predicts potential productivity at one or more sites on the basis of mean monthly climatic data. Other outputs are available, e.g. canopy leaf area index (LAI) and net primary production (NPP) around the time of canopy closure. The required output variables are identified by listing their names in the header row (Sec 2.5).

A number of runs are made for each site, depending on the choice of rainfall distribution and the presence or absence of a watertable, and output is averaged over each run. The choice of rainfall distribution, and how to output details for the separate runs for each site, are controlled by *PROMOD run time options* (Sec. 11).

The default parameters and run-time options may be changed at run-time using optional keywords.

5.2 *What input data are required?*

Input data for each site comprise site and stand factors, and monthly climatic data for one or more years. These data are read from the *site data* and *climate data sheets* (Secs. 9 and 10), named on the *Monthly PROMOD sheet*.

The parameters for the selected species are also read from a named *Parameter sheet*.

5.3 *What output is produced?*

Three types of output can be produced:

- The selected output variables averaged over each PROMOD run for a site are written in columns identified by their names. If a variable name is preceded by *Stdev*, *Max*, or *Min*, then the standard

deviation, maximum or minimum of that variable over each PROMOD run for a site is displayed rather than its mean value.

- If the *run-details* run-time option is on, values of the selected variables are also written to the *run-details output sheet* (see Sec. 11). If this sheet does not exist it is created, and if the *clear details* option is on, it is cleared before any output is written to it.
- Each output variable named on the *site data sheet* is written to that sheet in the column identified by its name.

5.4 Format of a Monthly PROMOD sheet

A *Monthly PROMOD sheet* is identified by the keywords **Monthly ProMod** in its top-left corner. An example is the sheet **MonthlyExample** in the workbook **ProModXL.data.xls**. Note the following points:

- Mandatory keywords are used to specify the species (keyword: **Species name**), and the *site data*, *climate data* and *parameter sheets* for this run (keywords: **Site data sheet**, **Climate data sheet**, and **Parameter sheet**, respectively). These are in the green block on the **MonthlyExample** sheet.
- The optional keywords **Parameter updates** locate a *parameter update block* which changes the default parameter values. Optional keywords can also be used to change the default run-time options. These are the brown data blocks on the example sheet **Sensitivity**.
- The keywords **Site name** determine the header row (Sec 2.5), listing the names of the optional output variables. Note that on a monthly PROMOD sheet no input variables are specified, so a blank cell must be to the right of **Site name** (but see Sec. 6 on sensitivity analyses).
- Site names are determined by scanning down the column containing **Site name**, omitting the cell below this keyword, until a non-blank cell is obtained. Site names are then read from this column until a blank cell is obtained. On **MonthlyExample**, sites ESP1 to v16 will be run, and note the use of header row and site name cells with spaces to format the data table (Sec 2.5).

5.5 How does a Monthly PROMOD run work?

When PROMODXL is run with a *Monthly PROMOD sheet* as the active sheet it:

- locates keywords for the species, and the site, climate and parameter sheets, and reads these data;
- reads default parameters for the named species from the parameter sheet, and assigns default run-time options;
- if there is a *parameter update block*, it uses this to update the default parameters;
- checks for changes to run-time options, and updates the default options as required;
- locates the **header row** and reads the required output variables;
- for each site, site data and monthly climate data are read from the selected *site data* and *climate data sheets*, PROMOD is run using this data, and the output variables named on the *Monthly ProMod* and *site data sheets* are written to those sheets.

6. Sensitivity analyses

Monthly PROMOD runs can also be used to perform sensitivity analyses of any PROMOD output with respect to any parameter, site or climatic factor. Three sensitivity runs are illustrated on the sheet **Sensitivity**. The one that will be run when the run button is pressed is determined by the location of **Site names** on the sheet. In each case, the graphs were set up using normal spreadsheet operations

A sensitivity analysis sheet is identified by the keywords **Sensitivity analysis**. Although the keywords **Monthly ProMod** also work, the use of **Sensitivity analysis** ensures that the help button accesses help appropriate for a sensitivity analysis rather than a monthly run.

For a normal *Monthly PROMOD run*, the header row has a blank column to the right of the site names. For a sensitivity analysis, columns of data to the right of the site names provide site inputs (Table 3) or PROMOD parameters (Table 5); then comes the blank column. These additional columns override data read from the *Site data sheet*, and after PROMOD parameters have been assigned from the *Parameters sheet* and through an *Update parameters block* on the active sheet. Thus the values listed in these columns for each site are those used for the site.

The output variables to be displayed are requested by listing their names in the header row.

The third example uses normal spreadsheet operations to enhance PROMODXL: type the name of a parameter or site input and its minimum and maximum values in the indicated cells, and the input block will be set up for a sensitivity analysis of PROMOD output with respect to that variable.

7. Predicting stand development

The measure of site productivity predicted by PROMOD can be used to derive the measure of site quality required by an empirical growth model. For example, for *E. globulus* and *E. nitens*, the peak MAI predicted by PROMOD is used to infer the site index employed by NITGRO (Candy 1997), which is then used to predict stand development (Battaglia et al. 1999). Stem mortality is not predicted.

A *Stand development sheet* is the interface to NITGRO, and is the vehicle for predicting stand development with PROMODXL.

7.1 What does a Stand development sheet do?

A stand development sheet uses NITGRO to predict stand development in either of two modes:

- as a *projection model*, where development is predicted following an inventory; or
- as a *yield model*, where likely development is predicted for a given site quality.

PROMOD run-time options, and parameter update blocks, are irrelevant to *Stand development sheets*.

7.2 What input data are required?

The input data are

- a switch selecting the mode, i.e. projection model or yield model;
- the inventory age, basal area and mean dominant height – used in only projection mode;
- the measure of site quality (site index or peak MAI) – used only in yield mode;
- the number of stems per hectare; and
- a list of ages at which stand development is required.

7.3 What output is produced?

The following output is produced:

a) *Summary results* – the stand volume at inventory, the site index at 15 years, the basal area at 10 years, the peak MAI, and stand age at peak MAI.

b) *Stand development* – for each stand age the number of stems, the stand basal area, mean dominant height and volume, the MAI, and the mean stem diameter.

7.4 Format of a Stand development sheet

A *Stand development sheet* is identified by the keywords **Stand development** in its top-left hand corner. An example is the sheet **StandDevelopment** in the workbook **ProModXL.data.xls**. Note that:

- The mandatory keyword **Run projection** model sets the mode of the model – **yes** for projection.

- The keywords **Projection model input** and **Yield model input** are required, depending on the mode, and locate the input data for that mode.
- The keywords **Summary results** sets the location of the summary output – 6 lines are required.
- The keywords **Stand age** sets the location of the detailed stand development output, and heads a column of stand ages for which this output is required. Ages are located by scanning down the column until a valid number is located, and the list is terminated by a blank cell or non-number.

7.5 *How does a stand development sheet work?*

When PROMODXL is run with a *Stand development* sheet as the active sheet it:

- determines the mode of the run and reads the required NITGRO input data;
- reads the list of stand ages; and
- runs NITGRO for each listed stand age and generates all required output.

8. Daily PROMOD runs

8.1 *What does a Daily PROMOD run do?*

A *Daily PROMOD run* uses PROMOD with daily meteorological data to predict the daily time course of variables such as NPP, canopy water use and soil water balance at a single site. The output variables required are identified by listing their names in a header row on the *Daily PROMOD sheet*.

The default parameter values can be changed at run-time using the **Parameter updates** keyword, but run-time options are ignored.

8.2 *What input data are required?*

The input data comprise the site and stand factors described in Table 3, and the daily meteorological data described in Sec. 4. The name of the species must also be specified.

8.3 *What output is produced?*

a) *Daily output*

Daily output is fully under the control of the user. It is defined by listing the names of the required output variables as column headings in the output region of the spreadsheet. Output for each day is on the same row as the meteorological input for that day, and in columns headed by the output variable names.

b) *Summary output*

The summary output comprises specific PROMOD output variables summed or averaged over the duration of the run and is written in a small block whose location is determined by the keywords **Output summary**.

8.4 *Format of a Daily PROMOD sheet*

A *Daily PROMOD* sheet is identified by the keywords **Daily ProMod** in its top-left corner. An example is the sheet **DailyExample** in the workbook **ProModXL.data.xls**. Note the following points:

- The mandatory keywords **Site data** locate the *site data input block*. This contains the site and stand factors, and must be as shown in **DailyExample**.
- The mandatory keywords **Output summary** determine where data summarising results over the period of the run are written. This block is 5 columns wide and 11 rows deep.
- The optional keywords **Parameter updates** locates a *parameter update block* containing run-time changes to default parameter values.

- The header row is identified by the keyword **Date** in column A, and determines the location of the daily meteorological input data, and the list of names of the required output variables.
- Daily meteorological data are in columns A-G in rows below the header row (the green region on **DailyExample**). The columns of data are as defined in Sec. 4. Each row contains data for a single day, there can be as many rows (days) as desired, and input is terminated by a blank row.
- The header row also contains, in column H onwards, the names of the desired output variables. Note the following:
 - valid output names are listed in Table 4;
 - a blank cell terminates the list of output names;
 - cells containing only spaces or a “-” indicate columns to be left blank.

8.5 How does a daily PROMOD run work?

When PROMODXL is run with a *Daily PROMOD* sheet as the active sheet it:

- locates the **Site data** and **Output summary** keywords;
- reads the site input data block and the default parameters for the selected species;
- if there is a parameter update block, it uses this to update the default parameters;
- searches for the **Date** keyword and determines daily output variables;
- runs PROMOD using the daily meteorological data, writes the daily output to the right of the input meteorological data for each day, and writes the summary output to the identified location.

9. The Site data sheet

9.1 What does a Site data sheet do?

A *site data sheet* specifies the names and values of factors characterising a site and its soil profile. *Monthly PROMOD* runs read data characterising sites from a *Site data sheet* and selected output can also be written back to the *Site data sheet*.

A *site data sheet* is also executable, with typical outputs being derived annual climatic factors and the maximum available soil water that can be stored in the soil profile.

9.2 Format of a Site data sheet

A *site data sheet* is identified by the keywords **Site data** in its top-left corner. An example is the sheet **SiteData** in the workbook **ProModXL.data.xls**. Note the following points:

- It must contain a *header row* with the keywords **Site name** in column A. You can have only one header row active on a *single site sheet*. (The sheet **SiteData** contains disabled examples of header rows for different levels of input detail.)
- Contiguous cells to the right of **Site name** in the header row contain the names of the input data to be read from this *site data sheet*. Note that:
 - the first variable name is in column B
 - valid input names are listed in Table 3
 - the list is terminated by a blank cell.
- To the right of this empty cell, names of optional output variables are placed. Note that:
 - valid output names are listed in Table 4
 - a blank cell terminates the list of output names
 - cells containing only spaces or a “-” indicate columns to be left blank.
- Site input data are in rows below the header row, with the site’s name in column A, and individual items in the columns defined by the names in the header row.

- There can be as many rows of site data as desired, and they can be separated by blank rows or by rows which do not contain site data.

9.3 How does a Site data sheet work?

When a *Monthly PROMOD* run uses a *Site data sheet* as an input data sheet:

- The header row is located by searching for the **Site name** keywords. It then reads the names of input variables given in the header row, and any further names as output variables. Remember: you can only have one header row on a *site data sheet*.
- When data for a specific site is required it searches column A for a cell whose text matches the name of the site and then reads the required data from that row. Note that:
 - the search ignores formatting and is not case sensitive;
 - if a match is found, it is assumed that the row contains valid site data;
 - the first matching cell determines the row read.

9.4 “Running” a Site data sheet

When a *Site data sheet* is executed:

- The header row is located and the names of data and output variables are read.
- Column A is scanned from the header row to the first non-blank cell. This and subsequent rows are assumed to contain site input data which is then processed by the *Site data* algorithm.
- The next blank cell in column A terminates scanning for sites.

10. The Climate data sheet

10.1 What does a Climate data sheet do?

A *Climate data sheet* is a data base of monthly climatic data for use by a *Monthly PROMOD* run. These data can be long-term means, or actual observed monthly means for a sequence of years. A *Climate data sheet* is NOT executable.

10.2 Format of a Climate data sheet

A *Climate data sheet* is identified by the keywords **Climate data** in its top-left corner. An example is the sheet **ClimateData** in the workbook **ProModXL.data.xls**. Note the following points:

- The site name is in column A
- The data listed in Sec. 4 are to the right of the site name, in blocks of 12 columns for January to December, each block corresponding to a climate variable in the order given in that list
- A single year’s data for a site is contained on a single row
- There can be more than one year’s data per site provided all rows for a site are contiguous and have the same site name.
- There can be as many rows of site climate data as desired, and they can be separated by blank rows or by rows which do not contain site data as long as the contents of column A does not match a site name.

10.3 How does a Climate data sheet work?

When PROMODXL reads a *Climate data sheet* for a specific site it:

- searches column A for the first cell whose contents match the name of the site (case and format are ignored) and then reads the climate data from that row;

- checks the next row to see if it also contains data for the same site, and if so it makes another run using that data;
- repeats this process until a blank cell in column A, or a different site name is encountered.

11. PROMOD run-time options

11.1 What are the run-time options?

Monthly PROMOD runs are controlled by a number of *run-time options*. Each option has a default setting assigned when a PROMOD workbook is opened. The options are as follows.

- Rainfall option* controls how PROMOD distributes rainy days in each month. The options are:
 - *Random*. A user-specified number of runs are made for each site with rainy days distributed randomly within each month and all results are averaged over these runs.
 - *Uniform*. A single run is made with the rainy days uniformly distributed in the month.
 - *Clumped*. A single run is made with all rainy days grouped at the start of the month.
 - *Default*. Runs are made with both the uniform and clumped distributions, and results are averaged over these two runs.
- True monthly version* selects the manner in which PROMOD uses monthly climatic data:
 - If this option is false, photosynthetic production, respiration, water use and water balance are calculated daily. It is assumed that each day has the same meteorological conditions, with the exception of rainfall which is as determined by *Rainfall option*.
 - If this option is true, light-limited photosynthetic production and respiration are calculated once per month, and all water-related calculations are daily. This halves execution time, and produces almost identical results.
- If *Timer on* is true, execution times for each site are displayed on the active PROMOD run sheet.
- If *Debug run* is true, predetermined daily calculations are summarised on specific sheets (which are usually hidden).
- If *Apply irrigation* is true, any irrigation schedule supplied on the climate sheet is applied.
- Run-details sheet* specifies the name of a sheet for displaying the results from each individual run for each site. For each site there will be one run for each rainfall distribution, and if a watertable is accessed each rainfall distribution is used with and without watertable access.
- If *Output run details* is true, results from each individual run are written to the run-details sheet.
- If *Clear details* is true, the run-details sheet is cleared before any results are written to it.

11.2 How to change run-time options?

Run-time options can be changed in two ways:

- The *Edit options* form can be used to modify the default settings of the options for this invocation of the workbook.
- Run-time options can be associated with a specific *Monthly PROMOD* spreadsheet by using keywords on that sheet to override the current default values for the options.

a) Use of the Edit options form

Open the Edit options form by pressing alt_R, or using the ProMod|Edit menu, and activate or deactivate switches and options as required. The Accept button establishes the new defaults, the Cancel button reverts to the current defaults, and the Defaults button reverts to defaults established when a workbook is opened.

b) Use of keywords on a Monthly PROMOD spreadsheet

The keywords listed in Table 6 can be used on a *Monthly PROMOD* spreadsheet to change the default run-time options for all runs initiated from that sheet.

12. References

The following are key references to the development and application of PROMOD, including papers referred to in the text:

- Battaglia, M. and Sands, P.J. (1997). Modelling site productivity of *Eucalyptus globulus* in response to climatic and site factors. *Australian Journal of Plant Physiology* 24: 831-850.
- Battaglia, M., Sands, P.J. and Candy, S.G. (1999). Hybrid growth model to predict height and volume growth in young *Eucalyptus globulus* plantations. *Forest Ecology and Management*, 120:193-201.
- Battaglia, M., Mummery, D. and Smith, A. (2001). Economic analysis of site survey and productivity modelling for the selection of plantation areas. *Forest Ecology and Management* in press.
- Candy, S. G. (1997). Growth and yield models for *Eucalyptus nitens* plantations in Tasmania and New Zealand. *Tasforests* 9: 167-198.
- Mummery, D., Battaglia, M., Beadle, C.L., Turnbull, C.R A. and McLeod, R. (1999). An application of terrain and environmental modelling in a large scale forestry experiment. *Forest Ecology and Management* 118:149-159.
- Mummery, D. and Battaglia, M. (2001). Environmental sensitivity analysis as a method of screening for prospective plantation sites: a case study with *E. globulus* in Tasmania. *Forest Ecology and Management* 140:51-63.
- Sands, P. J., W. Rawlins, and M. Battaglia. 1999. Use of a simple plantation productivity model to study the profitability of irrigated *Eucalyptus globulus*. *Ecological Modelling* 117:125-141.
- Sands, P.J., Battaglia, M. and Mummery, D. (2000). Application of process-based models to forest management: Experience with PROMOD, a simple plantation productivity model. *Tree Physiology*, 20: 383-392.

Table 1. Menus, toolbars and hot-keys

<i>Action</i>	<i>Menu item</i>	<i>Button caption</i>	<i>Hot-key</i>
Run PROMOD in a manner determined by the active spreadsheet	Run ProMod	Run	F10
Display a form for editing the default PROMOD run time options	Edit options	-	alt_r
Quit and unload PROMODXL	Quit ProMod	-	alt_x
Select and display a help topic from a sub-menu, e.g. a table of parameters or variable names	Help	-	-
Display the About form with credits and acknowledgements	About	About	F11
Display a help file appropriate to the active spreadsheet		Help	F12

Table 2. Spreadsheet classes

<i>Sheet class</i>	<i>What does the sheet do?</i>	<i>Executable?</i>
Monthly ProMod	Uses PROMOD to predict the productivity of many sites using monthly mean climatic data	Yes
Sensitivity analysis	Uses Monthly PROMOD runs to determine the sensitivity of PROMOD outputs to site, soil or climatic factors, or to PROMOD parameter values	Yes
Daily ProMod	Uses PROMOD to predict seasonal time-course of net primary production, canopy water use, available soil water, etc, of a single site using actual daily meteorological data	Yes
Stand development	Predicts the annual time course of canopy development, given an estimate of productivity for that site	Yes
Site data	Contains a data base of data characterising sites	Limited
Climate data	Contains a data base of monthly mean climatic data for sites	No
Parameter	Contains PROMOD parameters for various species	No

Table 3. PROMOD site data – variable names, units and comments

Variable name	Units	Meaning and comments
<i>Basic site information</i>		
lat	degrees	Site latitude, -ve in S hemisphere
drainage	-	0 if site is NOT subject to waterlogging, 1 otherwise
soilNO3	mg g ⁻¹	soil nitrate concentration
nutRating	-	Soil nutrient status on 0-1 ranking, 0 = no growth, 1 = no limitation. NB: takes precedence over nutClass
nutClass	-	Soil nutrient status on 0-4 ranking, 0 = no nutrient limitations
soilSalt	mS m ⁻¹	Salinity of 1:5 soil solution at depth of 1.5 m or bottom of profile
<i>Basic soil profile data</i>		
soilWaterCap	mm m ⁻¹	Mean intrinsic soil water holding capacity to root depth
rootDepth	cm	Depth to which roots penetrate the soil
maxASW	cm	Maximum available soil water to rooting depth
minASW	cm	Minimum ASW permitted to root depth – any deficit is assumed to be made up from a supplemental source
<i>Detailed soil profile data – these are used if rootDepth or soilWaterCap are 0</i>		
depthA	cm	Thickness of A profile
depthB	cm	Thickness of B profile
textA	-	Texture of A profile (1= good, to 5 = poor)
textB	-	Texture of B profile (1= good, to 5 = poor)
stonesA	-	Fraction of A profile volume occupied by stones (0-1)
stonesB	-	Fraction of B profile volume occupied by stones (0-1)
panThick	cm	Thickness of any pan between A & B profiles
panHard	-	Hardness of any pan between A & B profiles (0-10)
<i>Details of watertable</i>		
rotation	yr	Rotation length – only required when watertable is present
wtblDepth	cm	Depth to top of watertable; 0 ⇒ no watertable is present
wtblSalt	mS m ⁻¹	Salinity of the watertable
<i>Climate data modifiers – applied to climate data read from climate data input sheet</i>		
modQ	%	% increase to be applied to solar radiation
modTmax	°C	increase to be applied to maximum temperature
modTmin	°C	increase to be applied to minimum temperature
modEvap	%	% increase to be applied to open-pan evaporation
modRain	%	% increase to be applied to rainfall
modRaind	days	increase to be applied to number of rain days per month
<i>Observed canopy LAI and site productivity</i>		
obsMAI	m ³ ha ⁻¹ yr ⁻¹	Observed MAI – or other measure of site productivity
obsLAI	m m ⁻¹	Observed canopy leaf area index around canopy closure

Table 4. PROMOD output data – variable names, units and comments

Note: Prefix the output variable name with “max”, “min” and “stdev” to obtain the maximum, minimum or standard deviation of the variable over all runs for each site.

Variable name	Daily or Monthly run	Units	Meaning and comments
<i>Observed and predicted canopy LAI and site productivity</i>			
obsLAI	M	$m^2 m^{-2}$	Observed canopy leaf area index around the time of canopy closure
obsMAI	M	$m^3 ha^{-1} yr^{-1}$	Observed site productivity (usually peak mean annual increment)
LAI	M	$m^2 m^{-2}$	Predicted canopy leaf area index around the time of canopy closure
MAI	M	$m^3 ha^{-1} yr^{-1}$	Predicted site productivity (usually peak mean annual increment)
<i>Meteorological data for current day</i>			
Tx	D	°C	Maximum air temperature
Tn	D	°C	Minimum air temperature
Tam	D	°C	Mean temperature between sunrise and noon
Tpm	D	°C	Mean temperature between noon and sunset
Tav	D	°C	Mean temperature for day
Tmean	D	°C	10-day running mean daily mean temperature
Txmean	D	°C	10-day running mean daily maximum temperature
h	D	d	Daylength, fraction of day between sunrise and sunset
Qa	D	$MJ m^{-2} d^{-1}$	Total incoming solar radiation
Epan	D	$mm d^{-1}$	Open pan evaporation
Rain	D	$mm d^{-1}$	Daily rainfall
VPD	D	mbar	Mean daily vapour pressure deficit
<i>Site and climatic summary</i>			
aveC	M	-	Measure of water stress, annual mean daily crop factor without trees
nutRating	M	-	Site nutRating , based on soilNO3 or nutClass
TotalRain	M	$mm yr^{-1}$	Annual rainfall
RainDays	M	$d yr^{-1}$	Rainy days in year
TotalEvap	M	$mm yr^{-1}$	Annual pan evaporation
TotalQ	M	$GJ m^{-2} yr^{-1}$	Annual total incoming solar radiation
avTemp	M	°C	Annual average daily mean temperature
avTmax	M	°C	Annual average daily maximum temperature
avTmin	M	°C	Annual average daily minimum temperature
TotalIrrig	M	$mm yr^{-1}$	Total irrigation applied in year
IrrigDays	M	$d yr^{-1}$	Total days on which irrigation was applied
avTmax3	M	°C	Mean daily maximum temperature over warmest three months
avTmin3	M	°C	Mean daily minimum temperature over coldest three months
<i>Soil water variables</i>			
ASWmax	M	mm	Maximum available soil water that can be stored in soil profile
ASWintl	M	mm	Available soil water at start of year
ASW	M	mm	Available soil water at end of year
<i>Light interception and LAI calculations</i>			
totQint	M	$GJ m^{-2} yr^{-1}$	Annual total intercepted solar radiation
L	M	$m^2 m^{-2}$	Predicted canopy leaf area index around the time of canopy closure
Ltav	M	-	Effect of annual average temperature on LAI
Ltmin	M	-	Effect of average minimum temperature in coldest three months on LAI
Lrain	M	-	Effect of average water stress on LAI
Lnut	M	-	Effect of soil nutrition on LAI
<i>Canopy production and respiration</i>			
Aopt	D	$\mu mol m^{-2} s^{-1}$	Light saturated photosynthetic rate at optimum temperature
Topt	D	°C	Optimum temperature for photosynthesis
epsilon	D or M	$gDM MJ^{-1}$	Canopy light utilisation efficiency
GI	D or M	$tDM ha^{-1} yr^{-1}$	Contribution to GPP by days when photosynthesis is light limited
Gw	D or M	$tDM ha^{-1} yr^{-1}$	Contribution to GPP by days when photosynthesis is water limited
GPP	D or M	$tDM ha^{-1} yr^{-1}$	Annual gross primary production

<i>Variable name</i>	<i>Daily or Monthly run</i>	<i>Units</i>	<i>Meaning and comments</i>
NPP	D or M	tDM ha ⁻¹ yr ⁻¹	Annual net primary production
rC	D or M	-	Construction respiratory coefficient
rF	D or M	-	Foliage respiratory coefficient
rM	D or M	-	Maintenance respiratory coefficient
Y	D or M	-	Assimilate use efficiency
rootGrowth	M	cm yr ⁻¹	Annual downwards root growth
etaS	M	-	Fraction of NPP partitioned to stem (or productivity calibration ratio)
<i>Canopy water use and soil water balance</i>			
eC	D	-	Crop factor
isWlog	D	-	True if the site is water logged today, false otherwise
aET	D or M	mm yr ⁻¹	Annual evapotranspiration by the canopy
WUE	D or M	kgDM kg ⁻¹ H ₂ O	Annual stand water use efficiency
runoff	D or M	mm	Water lost due to surface run off or deep drainage
suplrrig	D or M	mm	Amount if water supplied to maintain ASW ≥ min ASW
wtblUse	D or M	mm	Amount of water drawn from watertable
indWstress	M	-	Index of water stress (annual mean daily crop factor with trees present)
indWlog	M	-	Index of waterlogging (fraction of year site is water logged)

Table 5. PROMOD parameters – symbols, variable names, units and comments

<i>Symbol</i>	<i>Variable name</i>	<i>Units</i>	<i>Meaning and comments</i>
<i>Single-leaf light response</i>			
α_0	alpha0	mol mol ⁻¹	Value of quantum efficiency (α) at temperature T_0
α_1	alpha1	°C ⁻¹	Temperature sensitivity of α
A_{opt}^*	Aopt*	mmol CO ₂ m ⁻² leaf s ⁻¹	Maximum value of A_x , i.e. value at $T=T_{opt}^*$
T_{opt}	Topt*	°C	Optimum temperature for photosynthesis
k	k	m ² ground m ⁻² leaf	Canopy extinction coefficient
θ	theta	-	Shape of single-leaf light response curve
$t_{1/2-}$	Thalf-	°C	Determines sensitivity of A_x to low diurnal temperatures
$t_{1/2+}$	Thalf+	°C	Determines sensitivity of A_x to high diurnal temperatures
a_{wl}	aWlog	-	Fraction by which water-logging reduces photosynthetic rate
<i>Photosynthetic acclimation to seasonal temperature</i>			
τ	tau	-	Determines extent of seasonal acclimation of T_{opt}
T_{pref}	Tpref	°C	Parameter determining seasonal acclimation of T_{opt}
$t_{1/2}^{*-}$	Thalf*-	°C	Determines acclimation of A_{opt} to low seasonal temperatures
$t_{1/2}^{*+}$	Thalf*+	°C	Determines acclimation of A_{opt} to high seasonal temperatures
<i>LAI submodel</i>			
-	LAloptn	-	Selects LAI functional response (1=standard, 2=radiata-type)
-	LAltempoptn	-	Selects photosynthetic temp. response (1=parabolic, 2=Gaussian)
L_x	Lmax	m ² leaf m ⁻² ground	Maximum of LAI
e_{c0}	wL0	-	Value of MeanCropFactor at which LAI=0
T_{Lopt}	LTopt	°C	Optimum mean temperature for LAI
T_{L0}	LT1	°C	Low-temperature threshold for mean temperature and LAI
T_{L1}	LT2	°C	High-temperature threshold for mean temperature and LAI
T_{Ln1}	LTn1	°C	Low-temperature threshold for coldest 3 months and LAI
T_{Ln2}	LTn2	°C	High-temperature threshold for coldest 3 months and LAI
L_{N4}	LN4	m ² leaf m ⁻² ground	Value of L_N for lowest fertility sites (nutClass = 4)
-	bNO3	-	Power in dependence of L_N on [NO ₃]
-	critNO3	mg g ⁻¹	Critical soil [NO ₃] = scale factor in dependence of L_N on [NO ₃]
<i>Soil-water balance and effects of ASW</i>			
w_0	w0	-	Value of relative ASW for which $e_c=0.5$
a_w	aw	-	Slope of linear portion of crop-factor v. relative ASW curve
-	wat crit	mm	Maximum value of ASW for effect of ASW on assimilation
w_0	omega0	gDM kPa kg ⁻¹ H ₂ O	Coefficient in WUE-VPD relationship
VPD_0	VPD0	kPa	Constant offset for VPD in WUE-VPD relationship
w_x	WUEx	gDM kg ⁻¹ H ₂ O	Maximum water-use-efficiency
S_{50}	S50	milliSiemens m ⁻¹	Conductivity in 1:5 extract (mSm ⁻¹) for 50% reduction in A or E
<i>Respiration parameters</i>			
r_c	respC	-	Construction respiratory coefficient
r_{M0}	respM	-	Woody tissue maintenance respiration coefficient
k_{dav}	kdav	°C ⁻¹	Temperature rate constant for dark respiration r_d
r_{d0}	rd0	mmol CO ₂ m ⁻² leaf s ⁻¹	Value of r_d at temperature T_0
k_{d0}	kd0	°C ⁻¹	Value of k_d at temperature T_0
k_{d1}	kd1	°C ⁻¹	Temperature sensitivity of $k_d(T_{av})$
k_M	Km	°C ⁻¹	Woody tissue temperature rate constant
<i>Calibration of productivity</i>			
b	b	-	Power in stem partitioning function
η_{Sx}	etaSx	-	Maximum partitioning to stem
G_0	G0	kgDM m ⁻² yr ⁻¹	Value of G at which $\eta_s=0.5$
ρ	density	kgDM m ⁻³	Mean density of stem wood
<i>Soil profile, hard pan, and watertable</i>			
-	pan1	-	These three constants determine the behaviour of hard-pans
-	pan2	-	
-	pan3	-	
W_{wl}	critASWwlog	-	Critical relative ASW for waterlogging
-	rootExtnRate	cm yr ⁻¹	Maximum annual vertical root growth

Table 6. PROMOD run-time options – keywords and comments

<i>Keyword</i>	<i>Meaning and comments</i>
<i>Distribution of rainy days</i>	
Rainfall option	Sets how rainy days are distributed in the month. Values are: <i>uniform</i> ⇒ rainy days are distributed as uniformly as possible in month <i>clumped</i> ⇒ rainy days are contiguous at the start of month <i>default</i> ⇒ make separate runs with uniform and clumped distributions <i>a number</i> ⇒ number of basic runs to make when rainy days are randomly distributed
<i>Run-time switches</i>	
True monthly version	If set to <i>Yes</i> , use true monthly version of PROMOD
Timer on	If set to <i>Yes</i> , display execution times for all sites
Debug run	If set to <i>Yes</i> , write predefined variables to debug sheets on a daily basis
Apply irrigation	If set to <i>Yes</i> , apply irrigation schedule defined on the climate data sheet
<i>Production of details of individual runs</i>	
Output run details	If set to <i>Yes</i> , write details from each run for each site to run-details sheet
Clear run details	If set to <i>Yes</i> , clear the run-details sheet before run-details are output
Run-details sheet	Specifies the name of the run-details sheet

Table 7. Input data required by a Daily PROMOD run***a) Site-specific input required for a Daily PROMOD run***

<i>Input identifier</i>	<i>Description of input</i>	<i>Units</i>
<i>Parameter sheet</i>	Name of a spreadsheet containing PROMOD parameter sets	
<i>Species</i>	Name of the species to be used	
<i>Latitude</i>	Site latitude, -ve in the S hemisphere	degrees
<i>Root depth</i>	Depth to which roots penetrate	cm
<i>Soil water capacity</i>	Amount of plant available soil water held per metre of soil	mm/m
<i>Site drainage</i>	0 \Rightarrow site is <i>not</i> subject to water logging 1 \Rightarrow site is subject to water logging	
<i>Soil salinity</i>	Salinity of 1:5 soil solution averaged over rooting depth	mSiemen m ⁻¹
<i>Watertable depth</i>	Depth to top of watertable	cm
<i>Watertable salinity</i>	Salinity of water in watertable	mSiemen m ⁻¹
<i>minASW</i>	Minimum available soil water. Any short fall is assumed to be made up by a supplemental source, e.g. irrigation	mm
<i>LAI</i>	The average canopy LAI during the period covered by run	
<i>Initial ASW</i>	Plant available soil water to root depth at the start of run	mm

b) Meteorological data required for a Daily PROMOD run

<i>Input name</i>	<i>Description of input</i>	<i>Units</i>
<i>Date</i>	Date of meteorological observation	
<i>dayOfYear</i>	Day of year, from January 1 st as 1	
<i>Tmax</i>	Maximum temperature	°C
<i>Tmin</i>	Minimum temperature	°C
<i>Q</i>	Total solar radiation	MJ m ⁻² day ⁻¹
<i>Rain</i>	Rainfall + irrigation	mm day ⁻¹
<i>Epan</i>	Open-pan evaporation	mm day ⁻¹

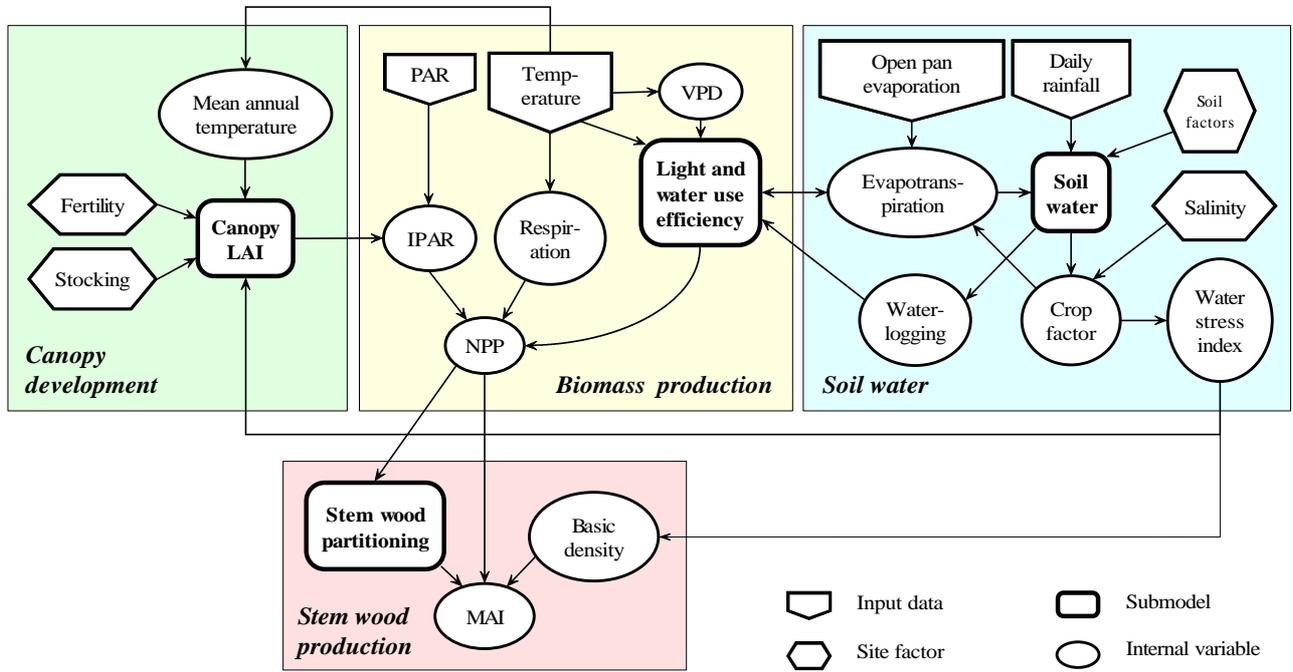


Fig. 1. Structure of PROMOD, and its input and output data.

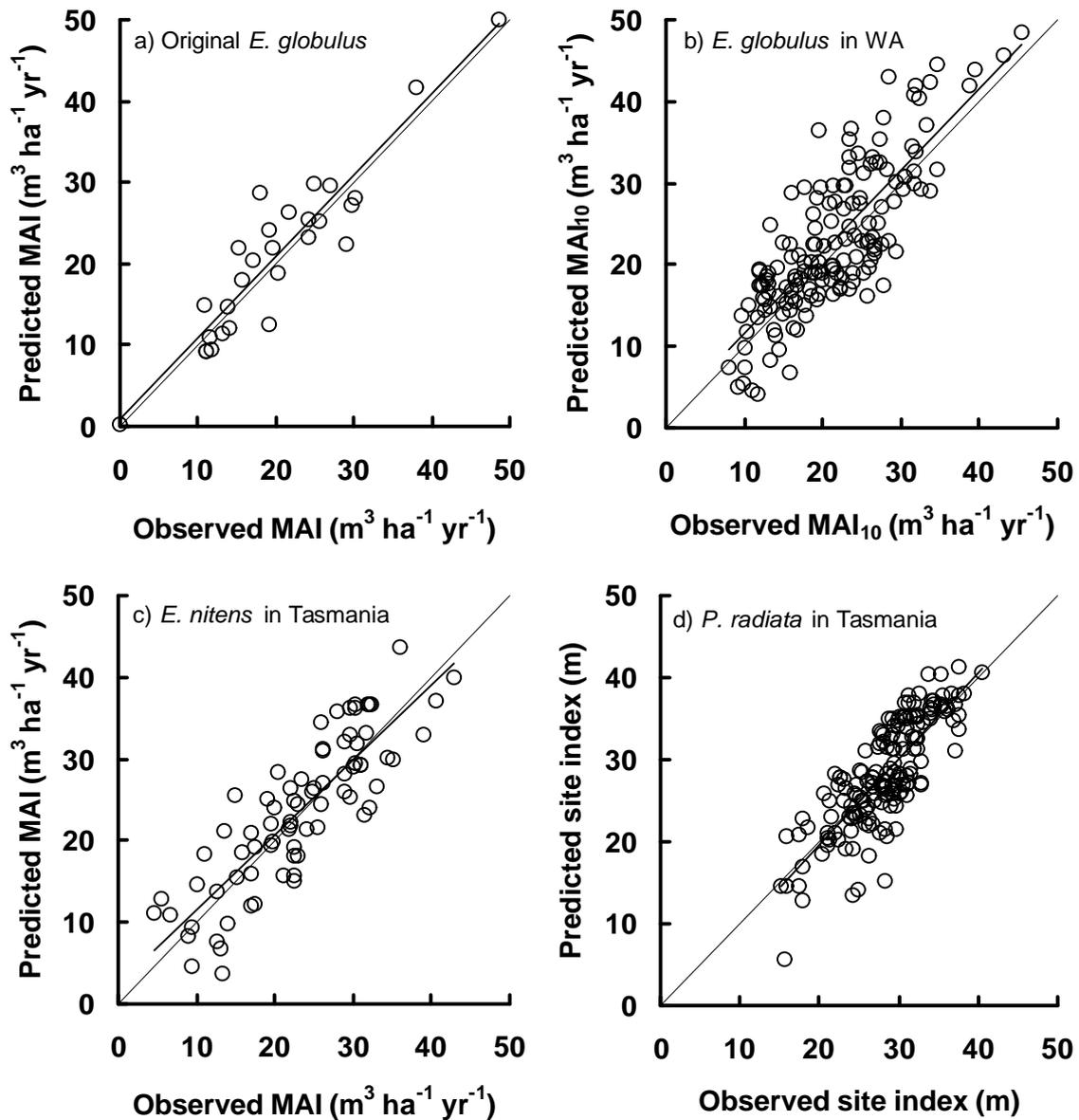


Fig. 2. Comparison of observed and predicted site productivity.

A comparison of the observed measures of site productivity with the corresponding values predicted using PROMOD for a number of species and sites:

- original *E. globulus* data sets originally used when developing PROMOD
- additional *E. globulus* sites in Western Australia, where the measure of productivity was MAI at 10 years;
- E. nitens* in Tasmania; and
- Pinus radiata* in Tasmania, where the measure of productivity is site index (mean dominant height at 15 years).