TreeMod

Growing a better future

ProFert

User Manual

Version 2.1

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TreeMod

Contents

Abbreviations

CAI (Current Annual Increment): increase in merchantable volume of a stand from the previous year to the current year.

IRR (Internal Rate of Return): a measure of profitability which calculates the effective % yield on an investment based on forecast future returns.

MAI (Mean Annual Increment): average annual increase in merchantable volume of a stand from planting to final harvest.

NPV (Net Present Value): a measure of profitability which discounts future costs and returns to their current value based on a rate input by the use.

PAI (Periodic Annual Increment): average annual increase in merchantable volume of a stand from the current age to the end of the rotation.

General Description of ProFert

ProFert is a tool for assessing the profitability of fertilising softwood plantations across southern Australia. This tool incorporates results of decades of fertilizer research into an-easy to use decision support system for forest managers.

ProFert predicts growth to the end of the rotation for up to four fertiliser applications and thinnings and estimates changes in product mix and value as well as increases in total wood production in response to a wide range of fertiliser types, combinations and years of application. This tool provides forest managers with the capacity to obtain reliable information on the most profitable stands to fertilise and the most profitable fertiliser regime to implement.

ProFert is designed to use readily available stand growth data. It can also use stand specific growth, product, harvest and haulage data provided by existing growth and yield systems. This ensures that its outputs are consistent with the information in these systems. Fertiliser response is calculated using the best available relationships available. These are based on foliar nutrient data but other data including soil data can be used instead if foliar data is unavailable

The model can be run in batch mode to assess multiple sites or can provide detailed information about selected sites. This allows the user to rapidly identify the most profitable sites to fertilise or to assess more detailed growth, yield and financial information for individual sites. The model can also automatically optimize fertiliser regimes to maximize either NPV (Net Present Value) or the amount of wood produced per dollar spent based on information provided by the user.

This manual provides detailed information on how to use ProFert Version 2.1. It covers data requirements, step by step instructions for running the model, and explanations of outputs. We hope you enjoy using ProFert and believe it will make a valuable contribution to your business.

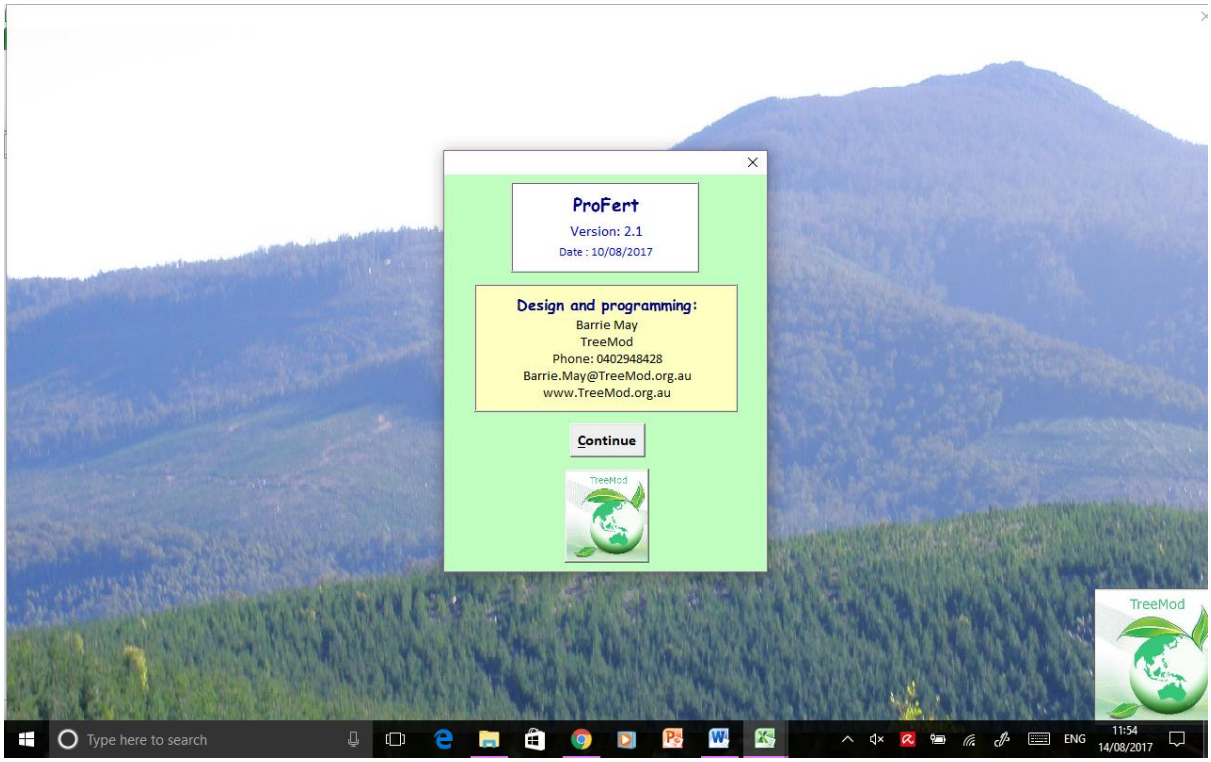
Getting Started

Purpose

ProFert is an excel-based decision support tool for selecting stands to fertilise and types and rates of fertiliser to apply over a full rotation. It is designed to be easy-to-use, flexible and efficient. It requires few inputs and can accept stand growth, yield, product and harvest cost information directly from existing systems. All that is required is information on foliar nutrient data and planned fertiliser regimes as well as fertiliser types and costs, stand age and proposed clearfell age.

Starting the tool

To run ProFert, Excel 2007 or later must be installed on your computer. Simply download the program and paste a shortcut to it on your desktop. Alternatively you can start excel first and then open the program from within Excel. You should then see the following screen:



Click *Continue* and *OK* go through the introductory information and disclaimer.

Selecting Data Mode

The next screen asks for the type of data that the user would like use to estimate stand growth rates and product yields (Figure 1). ProFert can be run either using regional growth curves or site specific data output by a growth and yield system. Note that, you can also change the data mode after starting ProFert by selecting a different mode on the Main Sheet.

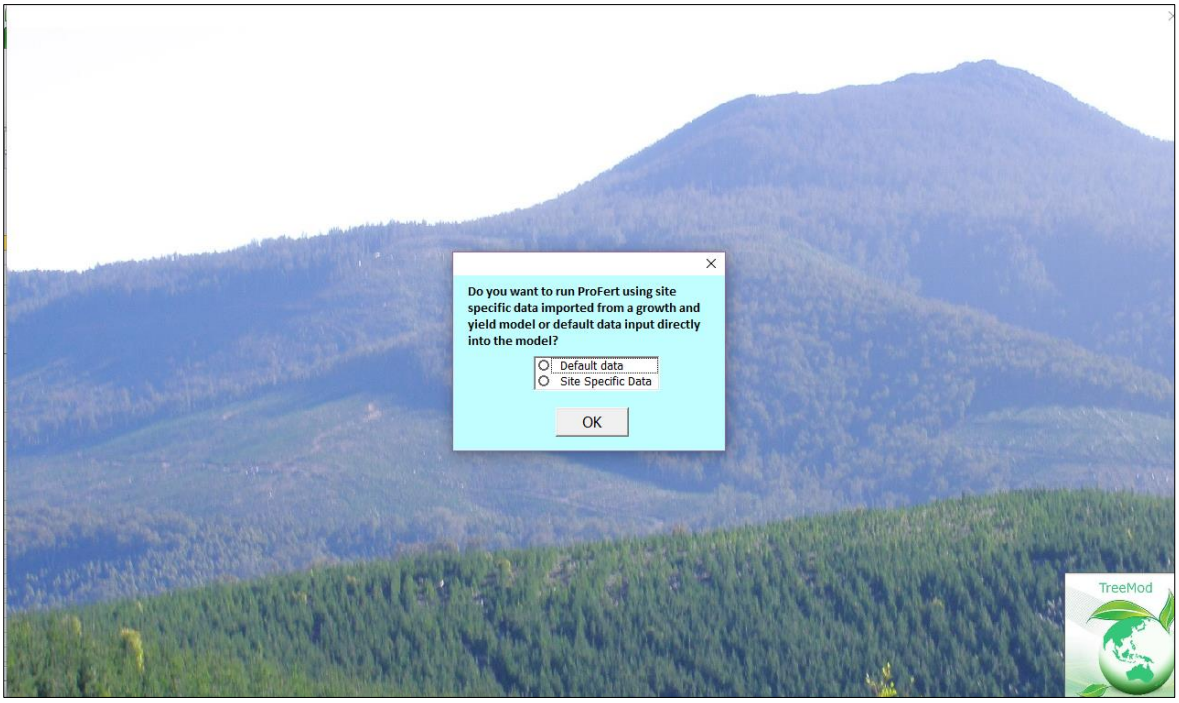


Figure 1: ProFert start-up window showing data mode for user to select.

Regional data

By selecting 'Regional data' the user directs ProFert to use regional growth and product yield data that is already loaded into the model. This data is used to estimate growth the unfertilised stand and to calculate the volume of different log types harvested in order to estimate total value. The current version of ProFert includes equations for regional growth curves and product breakdowns for the Green Triangle. However, if desired, other data can be loaded instead.

Site specific data

If you have site specific growth and product data for individual stands output from a growth and yield system such as YTGen, this can be used instead of Regional data by selecting the option Site specific data.

Site specific data can include:

- Predicted standing and harvested volumes of individual products as well as total stand at ages ranging from the current age to clearfell;
- Mill door values (total values excluding harvest and haulage costs) of products harvested;
- Costs of harvesting for different thinning and clearfell operations; and
- Costs of transporting different log products from different locations to their destinations.

As mentioned, it is possible to switch from one data mode to another after starting ProFert as explained in the following section.

Main sheet

After loading the model the *Main sheet* appears. This sheet is used for inputting data, running the model and viewing summary results. The format varies depending on the company for which the model has been tailored as the type and format of information available to run the model can vary from company to company. Figure 8, shows the *Main sheet* for as it appears in the demo version of the model.

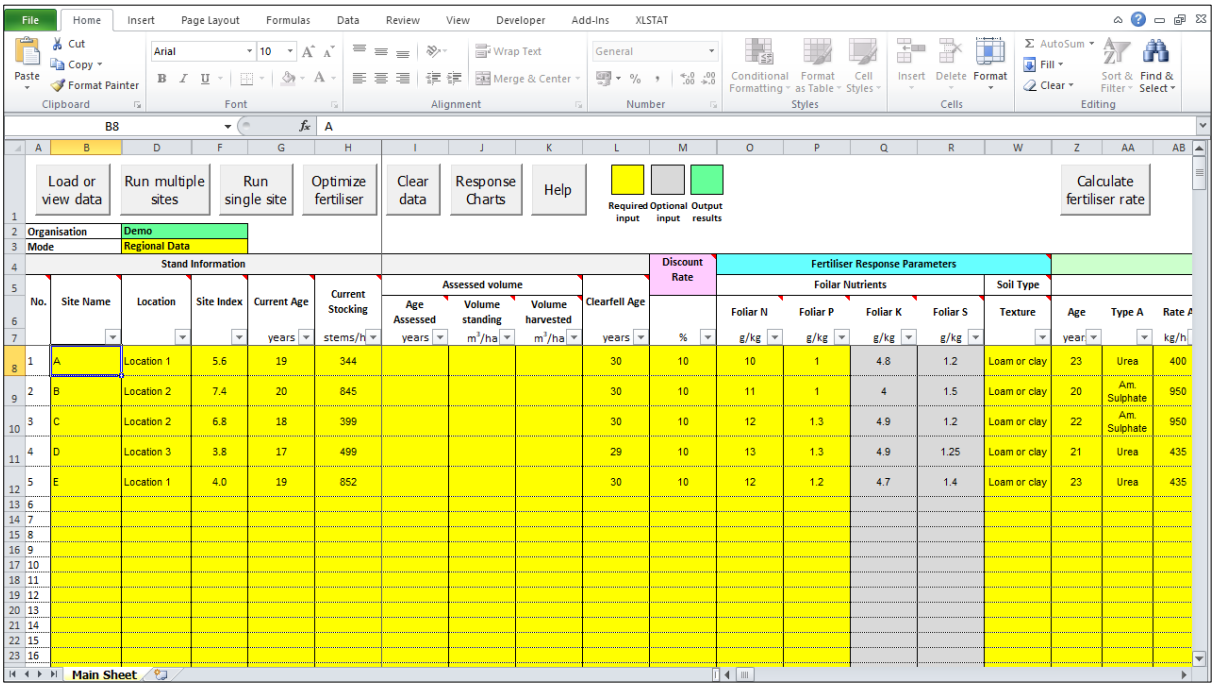


Figure 2: ProFert Main Sheet as it is displayed in the Demo version.

This sheet holds the key parameters required to run the tool. These include stand information, fertiliser response parameters, fertiliser events and thinning operations. Because the format and type of data that is available to run ProFert differs from company to company, the model has been specifically tailored to suit individual organisations. Currently, it has been set-up for four organisations:

- TPPL – Green Triangle;
- TPPL – Tasmania;
- HVP; and
- Norske Skog.

In addition, there is a demonstration version which uses a similar interface to that used by TPPL – Green Triangle. The columns visible in the Main sheet and the options available during loading data differ slightly for each company. This User Manual provides instructions for each company.

The columns in the *Main sheet* are colour coded as follows:

- Yellow: data that is required for the model to run (note that some of this data my by input automatically by the model;
- Grey: optional data that can be added; and
- Light Green: outputs from the model.

The sheet also includes a series of buttons along the top which allow the user to load data, run the model, clear inputs and outputs, view response functions, calculate fertiliser rates or go to a help menu. These functions are explained in the following sections.

ProFert Inputs

Loading Base Data

Before ProFert can be used, growth data, product recoveries and values, harvest and haulage costs and fertiliser types and costs must be loaded into the model. Default values including growth equations and product yields based on data from the Green Triangle and nominal product values and harvesting and haulage costs are included in the model, but these may need to be changed to obtain accurate results for your region.

Pressing the Load data button on the *Main sheet* brings up one of two menus. If the *Regional data* mode has been selected, it brings up the screen shown in Figure 3, otherwise, if *Site specific data* mode has been selected then it brings up the screen shown in Figure 4. The mode can be changed either when loading ProFert, or in the *Main sheet* by changing the selection in cell D3.

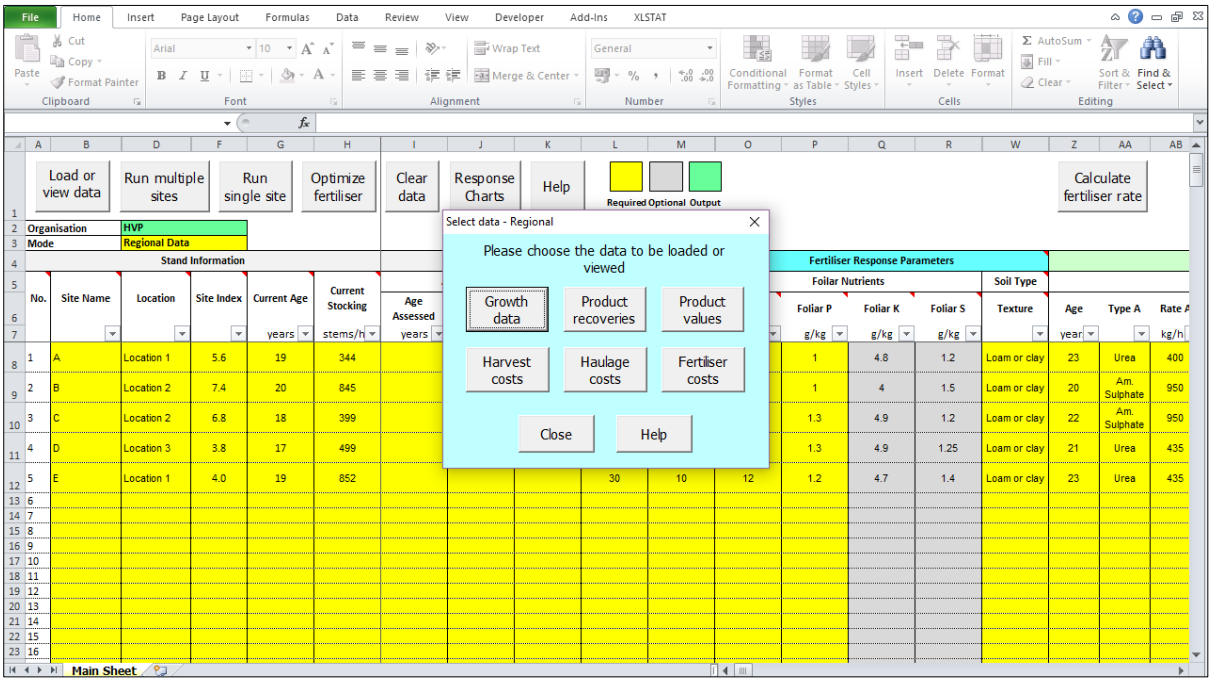


Figure 3: Data loading panels displayed when using a) Regional Data and b) Site Specific Data.

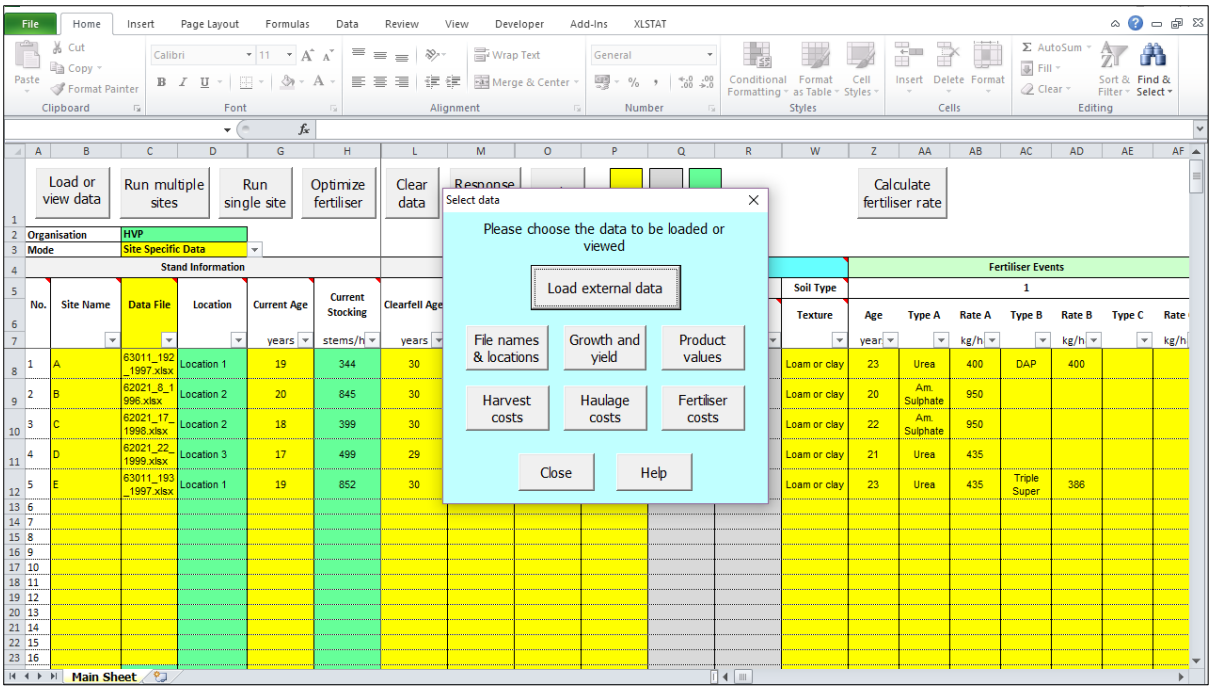


Figure 4: Data loading panels displayed when using a) Regional Data and b) Site Specific Data.

Loading Regional Data

When using the Regional Data mode, pressing the ***Load data*** button brings up a window with 6 buttons for loading data plus a *Close* and *Help* button (Figure 3). These buttons allow user to load:

- Regional growth data;
- Regional product recoveries;
- Product values;
- Harvesting costs;
- Haulage costs; and
- Fertiliser costs.

These options are explained in more detail below.

Regional growth data

Selecting *Regional growth data* from the Load data window brings up a worksheet titled *Gth. Data – Regional*. This sheet includes the equations and data used to calculate total wood volumes for unfertilised stands at different ages at site qualities (Figure 5).

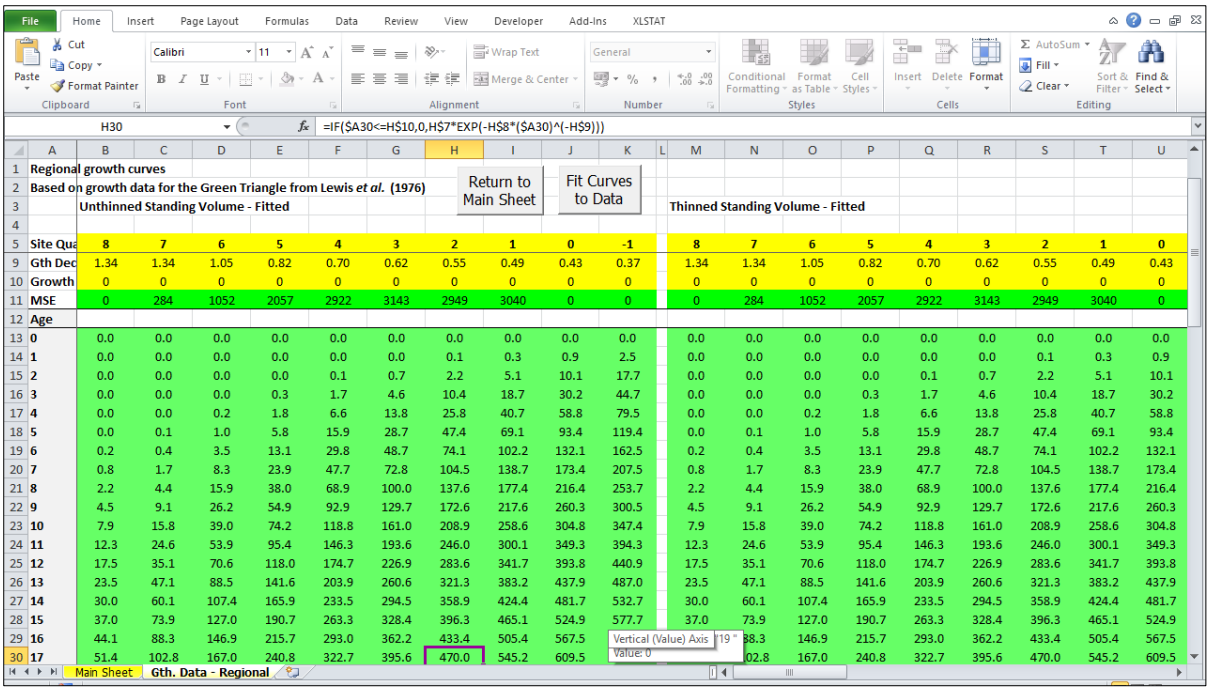


Figure 5: Regional growth data used to estimate growth rates of the controls in the demo version of ProFert.

The demonstration version of ProFert includes stand growth data for the Green Triangle from Lewis *et al.* (1976). This data includes tables of volumes x age for stand Site Qualities ranging from 1 (equivalent to an MAI of 35 m^3/ha/y) to 7 (equivalent to an MAI of 9 m^3/ha/y) and ranging in age from 10 years to 40 years. In ProFert, these tables have been converted into equations with stand age extrapolated back to age 1 year and the range of Site Qualities extended to cover a wider range of stand productivities (Figure 6). The function used to fit the curves has the general form:

$$V_a = M * e^{-AMax * a^{-d}}$$

where:

V_a is the stand volume at age a;

M is the maximum volume for the stand;

$AMax$ is the age of maximum growth; and

d is the rate of decline in growth.

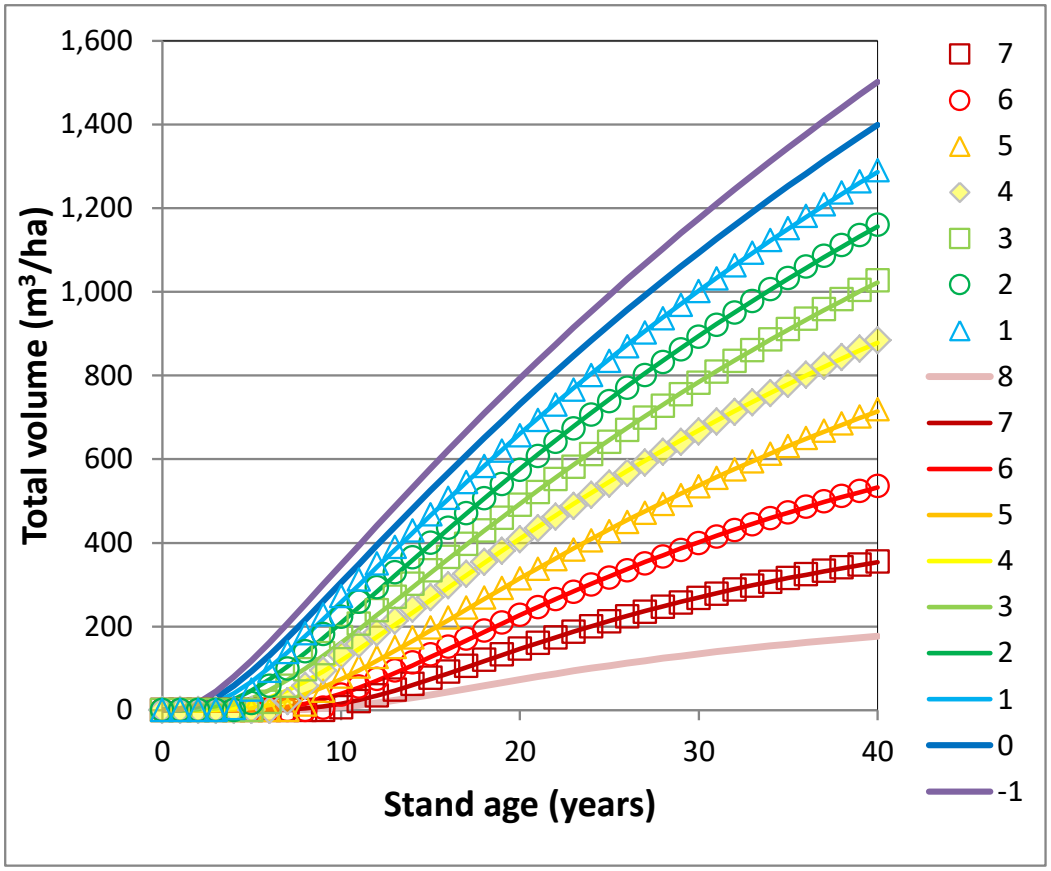


Figure 6: Regional stand growth curves included with ProFert based on data from the Green Triangle (derived from Lewis *et al.* 1976).

ProFert includes a function to automatically fit curves by using Solver to find the optimum parameters for the equation for each site quality. However, this function is currently disabled because it requires Solver to be referenced in the VBA libraries. If you would like this function enabled please contact Barrie May at TreeMod (see contact details on the last page of this manual).

Regional product recoveries

In the *Regional Data Mode*, product yields are estimated from tabulated values estimating the percentage recovery of different log sizes from trees of different volumes in the table in the sheet titled *Prod. Recovery* (Figure 7). The dataset included with ProFert is based on data from the Green Triangle (Figure 8). It includes 9 log classes (< 15 cm, 15-20 cm, 20-25 cm,…> 50 cm) and covers tree volumes ranging from 0.07 m^3 to 2.6 m^3.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Log breakdown data																					
2		Source:	Croptype yield tables & products; Typical harvest regime showing nominal stocking by thinning type									Return to Main Sheet										
3		Providor:	Rob Hannsen Timberlands																			
4		File Name:	TPPL Data V2.xls																			
5		Description	Original croptype yield data include total volumes by product and age for 91 regimes. Tree volume was estimated for each age and regime from the regime label (showing thinnin																			
6																						
7	% Recovery of Log Sizes (SED)																					C
8	Product name	Log A	Log B	Log C	Log D	Log E	Log F	Log G	Log H	Log I												Total
9	Log size (SED cm)	<15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	>50												
10	Tree Volume (m3)																					
78	0.664	23.59	11.33	29.75	22.58	10.62	2.12	0.00	0.00	0.00												
79	0.676	23.06	10.96	29.55	23.11	10.99	2.33	0.00	0.00	0.00												
80	0.703	21.85	10.11	29.10	24.32	11.84	2.79	0.00	0.00	0.00												100.0
81	0.726	20.86	9.42	28.70	25.31	12.54	3.18	0.00	0.00	0.00												100.0
82	0.759	19.94	8.85	27.73	26.17	13.45	3.83	0.04	0.00	0.00												100.0
83	0.792	19.02	8.27	26.76	27.03	14.37	4.48	0.07	0.00	0.00												100.0
84	0.810	18.52	7.97	26.24	27.49	14.86	4.83	0.09	0.00	0.00												100.0
85	0.840	17.69	7.45	25.36	28.27	15.68	5.42	0.12	0.00	0.00												100.0
86	0.852	17.38	7.26	25.04	28.56	15.99	5.63	0.14	0.00	0.00												100.0
87	0.886	16.44	6.68	24.05	29.44	16.92	6.30	0.17	0.00	0.00												100.0
88	0.907	15.87	6.32	23.45	29.97	17.49	6.70	0.19	0.00	0.00												100.0
89	0.941	15.28	6.03	22.53	29.93	18.35	7.32	0.56	0.00	0.00												100.0
90	0.952	15.10	5.94	22.23	29.88	18.63	7.52	0.70	0.00	0.00												100.0
91	0.985	14.55	5.68	21.33	29.73	19.48	8.13	1.10	0.00	0.00												100.0

Vertical (Value) Axis
Value: 0

Main Sheet | Prod. Recovery

Figure 7: Product recovery sheet showing recoveries of different products for different tree sizes based on data from the Green Triangle.

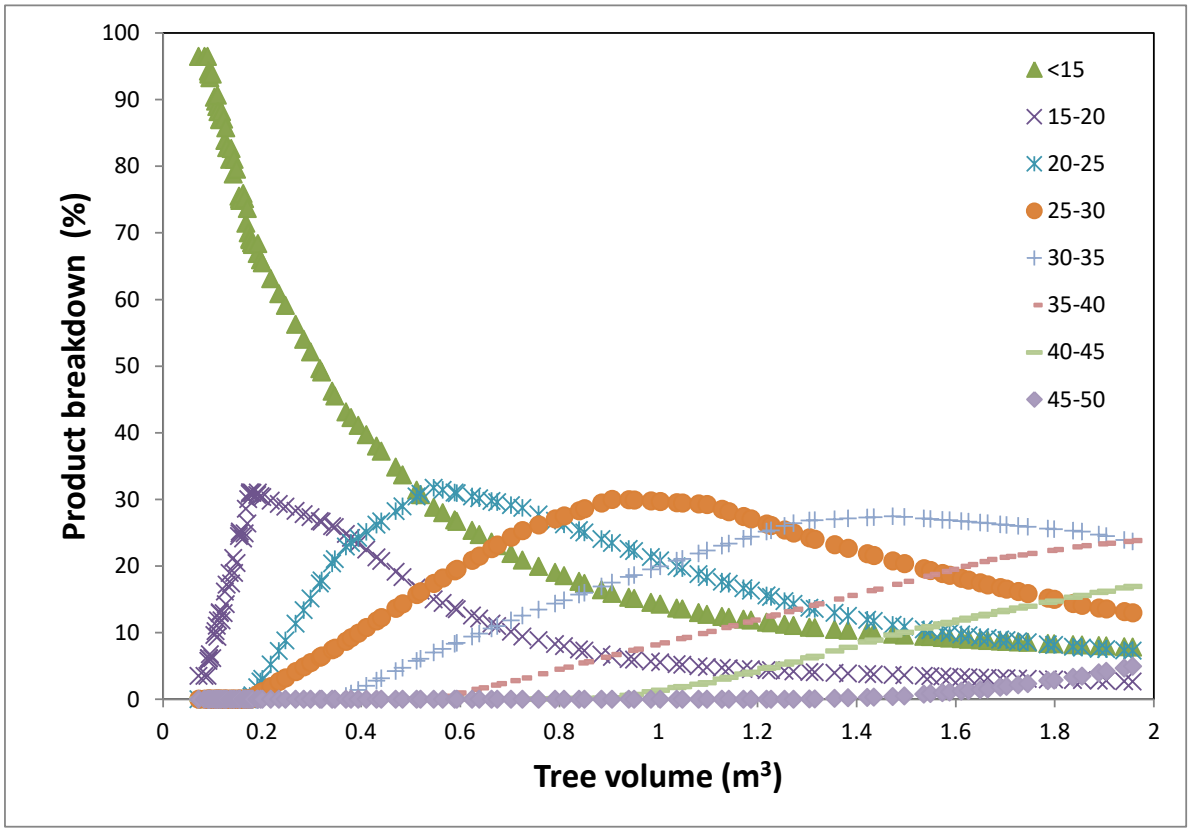


Figure 8: Regional log yields included with ProFert based on data from the Green Triangle.

Where local regional data is available, this can be entered into the data table instead of the default values from the Green Triangle. The log sizes and names for the different product types are automatically linked to the names entered into the table on the sheet *Prod. Values* and can only be changed on that sheet. However, tree sizes and the % breakdown of the different products can be entered manually into the table. When entering local data, make sure the tree volumes in column A are listed increasing size and that they cover the full range of tree volumes expected. Tree volumes outside this range will be assumed to be equal to that of the maximum (or minimum) volume listed.

Product values

The sheet titled *Prod. Values* includes the sizes, names, categories and values of the different log types (Table 1). The size ranges represent the small end diameters (SEDs) of the different log types and these, together with the product names, are automatically copied to the tables in the sheets *Prod. Recovery* and *Haulage costs*. Up to 20 names can be entered. However, each name must be unique (i.e. not repeated) in order to allow ProFert to calculate the values of harvested and standing trees correctly. If site specific growth and yield data are used, the names of the products in the *Prod. Values* sheet must be the same as those output by the growth and yield system (see section on *Loading Site Specific Data* for *TPPL*).

For product category, the user must select pulplog, sawlog or other. This allows ProFert to summarise the value and volume of each category of log produced. Product values must be mill door values (i.e. before costs of harvesting and transport are deducted).

Descriptions of the various products and comments can be optionally included.

Table 1: Product value sheet showing default product names and values.

Log Size (SED cm)	Product Description	Site Specific Data	Category	Product value ($/m3)	Comment
<15		Log A	Pulplog	30	
15-20		Log B	Pulplog	40	
20-25		Log C	Sawlog	50	
25-30		Log D	Sawlog	60	
30-35		Log E	Sawlog	70	
35-40		Log F	Sawlog	80	
40-45		Log G	Sawlog	90	
45-50		Log H	Sawlog	100	
>50		Log I	Sawlog	110	

Harvesting costs

The Harvesting costs button opens the table shown in Table 2. This table includes the types and costs of the various thinning, clearfell and non-commercial harvesting operations that can occur in different stands. If site specific data is used, then the names of operations in the *Harvesting Costs* table must be the same as those in the growth and yield data.

If the user enters harvesting information on the *Main Sheet* (see Section *Stand Inputs*) it is assumed that the harvest costs associated with the first thinning are those from the thinning operation listed first in the harvest cost table (e.g. *Thin1* in the example in Table 2). The costs associated with second thinning are assumed to be the next row (e.g. *Thin2*) and so on. If a thinning column is left blank in the Main Sheet then this particular thinning is assumed to be skipped. Up to four separate thinnings can be specified for a single stand.

Table 2: Harvesting operations and costs

Operation	Cost	Unit
THIN1	30	$/m3
THIN2	25	$/m3
THIN3	20	$/m3
THIN4	15	$/m3
CFELL	10	$/m3
NON-COMMERCIAL		$/ha

At final harvest, the stand is clearfelled and the harvest cost associated with the operation titled *CFell* is used. Non-commercial harvesting costs are applied to thinnings labelled as non-commercial in the *Main Sheet*.

Haulage costs

The *Haulage costs* button opens the following table (Table 3).

Table 3: Haulage costs for different products from different stand locations.

Haulage costs ($/t)

Return to Main Sheet | Help

Location	Product name and Destination								
	Log A	Log B	Log C	Log D	Log E	Log F	Log G	Log H	Log I
Average	16.20	8.40	11.60	17.40	13.00	16.80	16.80	16.80	16.80
Location 1	18	17	6	9	17	20	20	20	20
Location 2	9	9	20	16	8	19	19	19	19
Location 3	20	5	11	20	13	16	16	16	16
RE_F_1	20	5	11	20	13	16	16	16	16
KE_F_1	14	6	10	22	14	13	13	13	13

This table includes the costs for transporting different products from different locations. The product names in the 2nd row of the table are automatically linked to those in the *Prod. Values* sheet.

The left hand column has the name of the geographic location of each stand. It is assumed that there is only one destination for each product from each location. However, if there are more, an average cost for the two destinations can be used. The name of the destination for the products may be optionally included in the grey cells of the 3rd row of the table.

The row with the location *Average* has the average costs from all locations for each product. Where a location for a particular stand is not known, the user can use this average cost by specifying the location as *Average* on the *Main sheet.*

Fertiliser costs

The nutrient analysis and costs of different fertiliser types are stored in the sheet *Fertiliser costs* (Table 4). The user can add or remove fertiliser types, and change nutrient concentrations, purchase costs and application costs in this table. These fertiliser types are then available to be input into the *Main Sheet* as well as the optimizer procedure.

Table 4: Table of fertiliser types, analysis and costs.

Name	Analysis[1]						Cost		
	N %	P %	K %	S %	Ca %	Mg %	Fertiliser $/tonne	Application $/tonne	Total $/tonne
Urea	46.0	0.0	0.0	0.0	0.0	0.0	560	100	660
SCU	39.0	0.0	0.0	11.0	0.0	0.0	620	100	720
Agrotain Urea	46.0	0.0	0.0	0.0	0.0	0.0	720	100	820
Am. Sulphate	21.0	0.0	0.0	24.0	0.0	0.0	550	100	650
Am. Nitrate	35.0	0.0	0.0	0.0	0.0	0.0	900	100	1000
DAP	18.0	20.0	0.0	2.2	0.0	0.0	700	100	800
MAP	10.0	22.0	0.0	1.5	0.0	0.0	700	100	800
Triple Super	0.0	20.7	0.0	1.5	0.0	0.7	750	100	850
Super Phosphate	0.0	8.8	0.0	11.0	20.0	0.0	650	100	750
Rock Phosphate	0.0	3.2	0.0	0.0	20.0	0.0	650	100	750
KCl	0.0	0.0	51.0	0.0	0.0	0.0	350	100	450
NPKS-1	11.0	13.0	19.0	1.0	0.0	0.0	350	100	450

[1] Source: Impact Fertiliser at http://www.impactfert.com.au/products Accessed: 20/05 2013

Close

Pressing this button closes the selection panel for the *Load data* procedure

Help

The help button opens the help sheet and takes the user to the section on loading regional data. The help sheet includes most of the information contained in this user manual and contains menus for easy navigation.

Loading Site Specific Data

When using the Site Specific Data mode, pressing the ***Load data*** button brings up a window with 6 buttons for loading data plus a *Close* and *Help* button (Figure 4b). These buttons allow user to:

- Load site specific stand growth data, product yields, product values and harvesting and haulage costs;
- View names and locations of external files loaded into ProFert;
- View growth and yield data;
- View (or in the case of TPPL, load) Product values;
- View (or in the case of TPPL, load) Harvest costs;
- View (or in the case of TPPL, load) Haulage costs; and
- View and load Fertiliser costs.

The process for loading site specific data varies depending on the company using ProFert. HVP uses site specific data for growth, product recoveries, product values and harvesting haulage costs. However, TPPL uses site specific data for growth ad product recovery only, with regional averages used for product values and harvesting and haulage costs. The methods for loading and viewing data for the different organisations are explained below.

HVP

Most data required to run ProFert can be output directly from the YTGen growth and yield system as excel files. Provided the format is correct, data for multiple sites can be loaded automatically into ProFert by simply specifying the directory and selecting the names of the required files and worksheets. Examples of the correct format for worksheets to load stand growth data, product values and harvesting and haulage costs are shown in Table 5.

The data for each site must be included in a single excel workbook, but can be on separate sheets. For each stand, three tables of data are required:

1. Growth, harvest and product yield data (Table 5a);
2. Product name, type and value (Table 5b); and
3. Harvesting and haulage cost for each thinning and clearfell operation (Table 5b).

The tables can include any number of rows or columns. However, the headings for the *Product values* table and the *Harvest and haulage costs* table must be as shown in the templates for ProFert to correctly identify them. For growth data, the number of years of projected future growth projections should exceed the expected clearfell age by at least 10 years to allow the model to accurately estimate product yields where average tree size increases in response to fertiliser beyond that projected for the unfertilised stand at clearfell. For harvesting and haulage costs, the names of specific products and harvesting and haulage operations must exactly match those in the growth data sheet.

To load the data, select the *Load data* button on the *Main sheet* then select *External data.* ProFert first prompts the user to select the sites to load data for (Figure 9a). Then ProFert prompts the user to select the directory, file and sheet names with the required data (Figure 9b). If all files are in the same directory and have the same sheet names, ProFert can record this information, making it faster and easier to load data for subsequent sites.

Once the user has loaded all data and runs the model, the buttons labelled *Product values*, *Harvest costs*, *Haulage costs* open the sheets containing data for the last site which has been run by ProFert. This information is copied across from the source files when ProFert is run and is cleared and copied over for each successive site. Data for the last site run from each batch can be viewed by pressing the relevant button from the Load data menu. This allows the user to view the growth and yield data (Table 6a), product value data (Table 6b) or haulage cost data (Table 6c) for the last site included in the batch.

ProFert does not store the actual data loaded for each site, but rather the path, filename, sheet name and cell references for each data table. This information can be viewed by pressing the button *Files names and locations* (Figure 10).

Table 5: Templates for site specific a) growth and yield data and b) product values and harvesting and haulage costs required for ProFert. Note: values are for demonstration purposes only and do not necessarily reflect actual figures.

a)

Stand ID	Location	Age	Standing/ Harvested	Stocking	Total Volume	Recoverable Volume	Rec Volume Std Err	Chip	Log_A	Log_B	Log_C	Log_D	Log_E	Log_F	Log_G	Log_H	Log_I	Log_J	Log_K	Log_L
Site 100	KE_F_1	19	CFELL	400	246.3	234	12.3	10	11	12	50	1	80	65	5					
Site 100	KE_F_1	20	CFELL	400	254.0	241.3	12.7	9.8	12	12.5	49	1	78	66	8	5				
Site 100	KE_F_1	21	CFELL	400	259.6	246.6	13.0	9.6	13	13	48	1	76	67	11	8				
Site 100	KE_F_1	22	CFELL	400	267.3	253.9	13.4	9.4	14	13.5	47	1	74	68	14	11	1		1	
Site 100	KE_F_1	23	CFELL	400	273.9	260.2	13.7	9.2	14	14	46	1	72	69	17	14	2		2	
Site 100	KE_F_1	23	THIN3	300	280.5	266.5	14.0	9	14	14.5	45	1	70	70	20	17	3		3	
Site 100	KE_F_1	24	CFELL	300	287.2	272.8	14.4	8.8	14	15	44	1	68	71	23	20	4		4	
Site 100	KE_F_1	25	CFELL	300	293.8	279.1	14.7	8.6	14	15.5	43	1	66	72	26	23	5		5	
Site 100	KE_F_1	26	CFELL	300	302.5	287.4	15.1	8.4	14	16	42	1	64	73	29	26	6	1	6	1
Site 100	KE_F_1	27	CFELL	300	310.5	295	15.5	8.2	14	16.5	41	1	62	74	32	29	7	2	7	1.3
Site 100	KE_F_1	28	CFELL	300	318.3	302.4	15.9	8	14	17	40	1	60	75	35	32	8	3	8	1.4
Site 100	KE_F_1	29	CFELL	300	326.2	309.9	16.3	7.8	14	17.5	39	1	58	76	38	35	9	4	9	1.6
Site 100	KE_F_1	30	CFELL	300	335.2	318.4	16.8	7.6	14	18	38	1	56	77	41	38	10	5	10	2.8
Site 100	KE_F_1	31	CFELL	300	343.9	326.7	17.2	7.4	14	18.5	37	1	54	78	44	41	11	6	11	3.8
Site 100	KE_F_1	32	CFELL	300	354.0	336.3	17.7	7.2	14	19	36	1	52	79	47	44	12	7	12	6.1
Site 100	KE_F_1	33	CFELL	300	363.9	345.7	18.2	7	14	19.5	35	1	50	80	50	47	13	8	13	8.2
Site 100	KE_F_1	34	CFELL	300	378.5	359.6	18.9	6.8	14	20	34	1	48	81	53	50	14	9	14	14.8
Site 100	KE_F_1	35	CFELL	300	388.8	369.4	19.4	6.6	14	20.5	33	1	46	82	56	53	15	10	15	17.3

b)

Product values ($/m3 Mill Door)			Harvest and haulage costs ($/m3)																
Product	Category	Price ($/m3)	Location	Variable	Operation	Chip	Log_A	Log_B	Log_C	Log_D	Log_E	Log_F	Log_G	Log_H	Log_I	Log_J	Log_K	Log_L
Chip	Pulplog	30	KE_F_1	Harvesting	CFELL	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64
Log_A	Other	40	RE_F_1	Harvesting	CFELL	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64	9.64
Log_B	Other	50	RE_F_1	Harvesting	THIN3	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04
Log_C	Other	60	KE_F_1	Harvesting	THIN3	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04	13.04
Log_D	Other	70	KE_F_1	Haulage	CFELL	10.62	10.62	10.62	10.62	10.62	27.88	27.88	27.88	27.88	27.88	27.88	27.88	27.88
Log_E	Sawlog	80	RE_F_1	Haulage	CFELL	10.94	10.94	10.94	10.94	10.94	32.88	32.88	32.88	32.88	32.88	32.88	32.88	32.88
Log_F	Sawlog	90	RE_F_1	Haulage	THIN3	10.94	10.94	10.94	10.94	10.94	32.88	32.88	32.88	32.88	32.88	32.88	32.88	32.88
Log_G	Sawlog	100	KE_F_1	Haulage	THIN3	10.62	10.62	10.62	10.62	10.62	27.88	27.88	27.88	27.88	27.88	27.88	27.88	27.88
Log_H	Sawlog	110																
Log_I	Sawlog	120																
Log_J	Sawlog	130																
Log_K	Sawlog	140																
Log_L	Sawlog	150																

a) b)

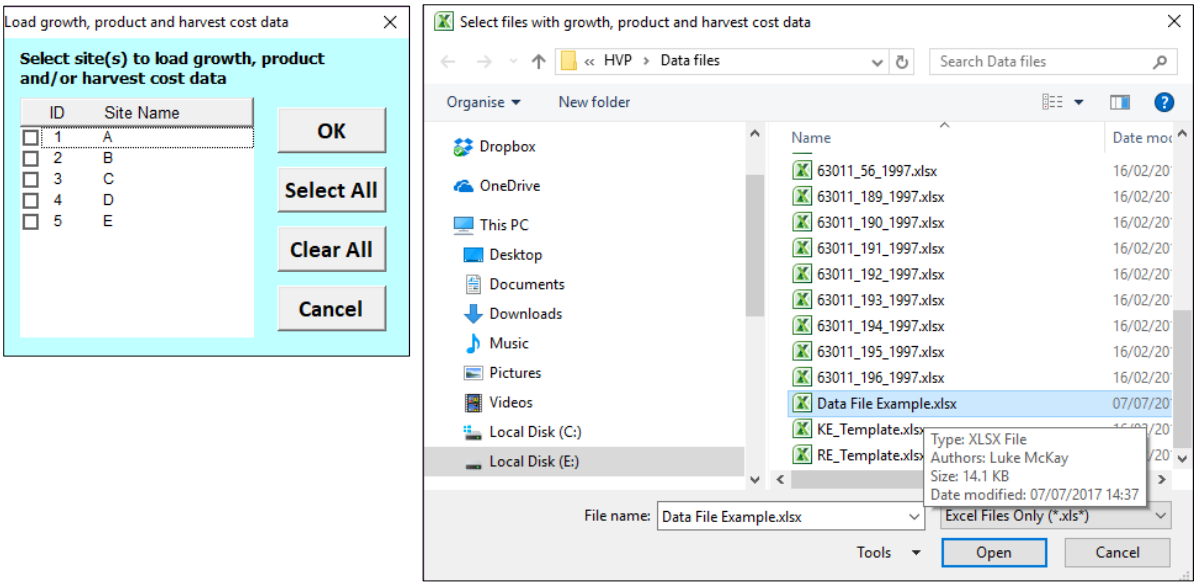


Figure 9: Prompts for user to a) select sites to load data for and the b) select the location and name of each file when loading site specific data into the model.

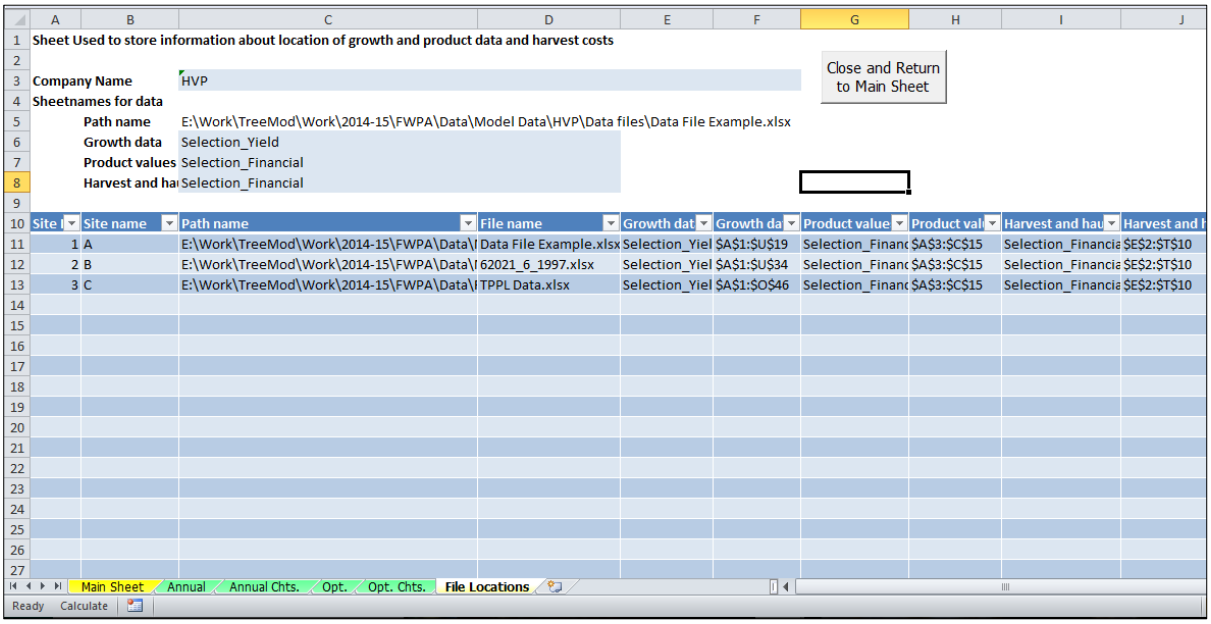


Figure 10: Example of file and worksheet names and locations and cell ranges holding growth and yield, product value and harvest and haulage cost data to be loaded into ProFert when run in site specific mode by HVP.

The button, *Fertiliser costs* opens the sheet which includes fertiliser nutrient analyses and costs as explained in the section on *Regional data* (Table 4).

Table 6: Example of site specific a) growth and yield, b) product value, and c) harvest and haulage cost tables loaded into ProFert. Note: values are for demonstration purposes only and do not necessarily reflect actual figures.

a)

Stand ID	Location	Age	Operation	Stocking	Total Volume	Recoverable Volume	Rec. Vol. Std Err	Chip	Log_A	Log_B	Log_C	Log_D	Log_E	Log_F	Log_G	Log_H	Log_I	Log_J	Log_K	Log_L
Site 100	KE_F_1	19	CFELL	400	246.3157895	234	12.315789	10	11	12	50	1	80	65	5					
Site 100	KE_F_1	20	CFELL	400	254	241.3	12.7	9.8	12	12.5	49	1	78	66	8	5				
Site 100	KE_F_1	21	CFELL	400	259.5789474	246.6	12.978947	9.6	13	13	48	1	76	67	11	8				
Site 100	KE_F_1	22	CFELL	400	267.2631579	253.9	13.363158	9.4	14	13.5	47	1	74	68	14	11	1		1	
Site 100	KE_F_1	23	CFELL	400	273.8947368	260.2	13.694737	9.2	14	14	46	1	72	69	17	14	2		2	
Site 100	KE_F_1	23	THIN3	300	280.5263158	266.5	14.026316	9	14	14.5	45	1	70	70	20	17	3		3	
Site 100	KE_F_1	24	CFELL	300	287.1578947	272.8	14.357895	8.8	14	15	44	1	68	71	23	20	4		4	
Site 100	KE_F_1	25	CFELL	300	293.7894737	279.1	14.689474	8.6	14	15.5	43	1	66	72	26	23	5		5	
Site 100	KE_F_1	26	CFELL	300	302.5263158	287.4	15.126316	8.4	14	16	42	1	64	73	29	26	6	1	6	1
Site 100	KE_F_1	27	CFELL	300	310.5263158	295	15.526316	8.2	14	16.5	41	1	62	74	32	29	7	2	7	1.3
Site 100	KE_F_1	28	CFELL	300	318.3157895	302.4	15.915789	8	14	17	40	1	60	75	35	32	8	3	8	1.4
Site 100	KE_F_1	29	CFELL	300	326.2105263	309.9	16.310526	7.8	14	17.5	39	1	58	76	38	35	9	4	9	1.6
Site 100	KE_F_1	30	CFELL	300	335.1578947	318.4	16.757895	7.6	14	18	38	1	56	77	41	38	10	5	10	2.8
Site 100	KE_F_1	31	CFELL	300	343.8947368	326.7	17.194737	7.4	14	18.5	37	1	54	78	44	41	11	6	11	3.8
Site 100	KE_F_1	32	CFELL	300	354	336.3	17.7	7.2	14	19	36	1	52	79	47	44	12	7	12	6.1
Site 100	KE_F_1	33	CFELL	300	363.8947368	345.7	18.194737	7	14	19.5	35	1	50	80	50	47	13	8	13	8.2
Site 100	KE_F_1	34	CFELL	300	378.5263158	359.6	18.926316	6.8	14	20	34	1	48	81	53	50	14	9	14	14.8

b)

Product name	Product category	Product value ($/m3)
Chip	Pulplog	30.00
Log_A	Other	40.00
Log_B	Other	50.00
Log_C	Other	60.00
Log_D	Other	70.00
Log_E	Sawlog	80.00
Log_F	Sawlog	90.00
Log_G	Sawlog	100.00
Log_H	Sawlog	110.00
Log_I	Sawlog	120.00
Log_J	Sawlog	130.00
Log_K	Sawlog	140.00
Log_L	Sawlog	150.00

c)

Location	Variable	Operation	Chip	Log_A	Log_B	Log_C	Log_D	Log_E	Log_F	Log_G	Log_H	Log_I	Log_J	Log_K	Log_L	
KE_F_1	Harvesting	CFELL	10	10	10	10	10	10	10	10	10	10	10	10	10	
RE_F_1	Harvesting	CFELL	11	11	11	11	11	11	11	11	11	11	11	11	11	
RE_F_1	Harvesting	THIN3	12	12	12	12	12	12	12	12	12	12	12	12	12	
KE_F_1	Harvesting	THIN3	13	13	13	13	13	13	13	13	13	13	13	13	13	
KE_F_1	Haulage	CFELL	14	14	14	14	14	14	14	14	14	14	14	14	14	
RE_F_1	Haulage	CFELL	15	15	15	15	15	15	15	15	15	15	15	15	15	
RE_F_1	Haulage	THIN3	16	16	16	16	16	16	16	16	16	16	16	16	16	
KE_F_1	Haulage	THIN3	17	17	17	17	17	17	17	17	17	17	17	17	17	

TPPL

Site specific data can be also loaded into ProFert using the TPPL version of the model. This loads site specific data for stand growth and yield only. The loading process is identical to that used in the HVP version except that the user is prompted for the location of only one table of data (that containing the growth and yield) rather than three tables (Figure 9). The locations of the source data files, worksheet names and ranges for the growth data used in each site can be view and edited by selecting the button *Files names and locations* (Figure 10).

In the TPPL version, data for product values, harvest costs, haulage destinations and costs and fertiliser types and costs are entered manually in the same way as for regional data (see the section Loading Regional Data). The names of specific products and harvesting and haulage operations used in the sheets *Prod. Values, Harv. costs* and *Haul. costs* must exactly match those used in the site external worksheets containing growth and yield data (Tables 1, 2 and 3).

Norske Skog

Only one mode, *Site Specific Data* mode is used for Norske Skog because the company provided the full growth model used to estimate growth and product yields for individual sites. As with TPPL, regional product values and harvest and haulage costs must be entered manually by the user. The *Data Load* screen consists of 5 buttons (Figure 11).

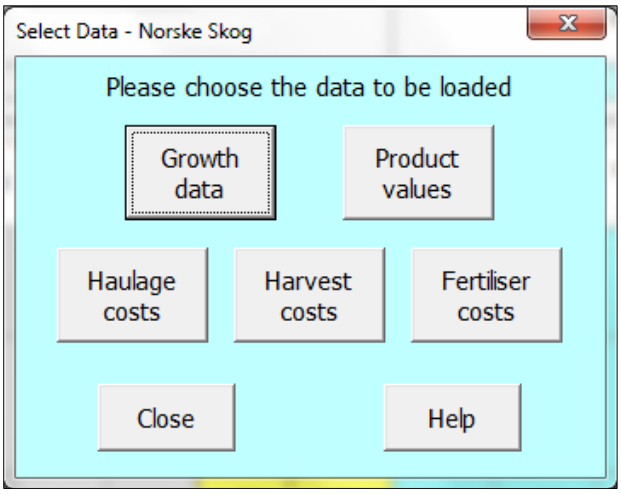


Figure 11: Norske Skog load data tab.

Growth data

The *Growth data* button opens up the tab containing growth and yield data for Norske Skog's growth model. The information must be in the same format as that shown in Table 8. The table consists of 12 columns which contain:

- Crop type;
- Stand age;
- Stocking (stems/ha);
- Total clearfell volume: volume of standing trees (m^3/ha);
- Total thinning volume: volume of harvested trees (m^3/ha);
- A blank column;
- 3 columns for products harvested at thinning (m^3/ha); and
- 3 columns with products harvested at clearfelling (m^3/ha).

Product values

The *Product values* button opens the table for inputting product types and values (Table 7). Product names are automatically linked to those in the *Growth data* sheet. However, the user must input the category and value for each product. Product descriptions and comments are optional.

Table 7: Table for inputting product categories and values for Norske Skog. Note: values are for demonstration purposes only and do not necessarily reflect actual figures.

3	Product Description	Site Specific Data	Category	Product value ($/m3)	Comment
4		T1PULP	Pulplog	30	
5		T2PULP	Pulplog	40	
6		T2KLOG	Sawlog	50	
7		CFPULP	Pulplog	60	
8		CFKLOG	Sawlog	70	
9		CFALOG	Sawlog	80	
10					
11					
12					

Other buttons

The *Haulage costs*, *Harvest costs* and *Fertiliser costs* buttons open the tables shown in *Loading Regional Data* (Tables 2, 3 and 4). As with other versions, the specific name of each product and each harvesting and haulage operation must exactly match that used in the growth and yield data sheet (Table 8).

Table 8: Example of the format for the data sheet with growth and yield data for Norske Skog. Note: values are for demonstration purposes only and do not necessarily reflect actual figures.

Crop Type	Age	Stocking	Total Clearfall Volume	Total Thinning Volume		T1PULP	T2PULP	T2KLOG	CFPULP	CFKLOG	CFALOG
A3	10	1200	230	0		0	0	0	200	30	0
A3	11	1200	260	0		0	0	0	220	40	0
A3	12	1200	290	0		0	0	0	240	50	0
A3	13	1200	320	0		0	0	0	250	70	0
A3	14	500	200	150		150	0	0	120	80	0
A3	15	500	230	0		0	0	0	140	90	0
A3	16	500	260	0		0	0	0	150	110	0
A3	17	500	290	0		0	0	0	160	150	0
A3	18	500	330	0		0	0	0	160	170	0
A3	19	290	260	100		0	80	20	90	160	10
A3	20	290	290	0		0	0	0	100	170	20
A3	21	290	320	0		0	0	0	100	190	30
A3	22	290	350	0		0	0	0	110	200	40
A3	23	290	380	0		0	0	0	110	210	60
A3	24	290	410	0		0	0	0	110	220	80
A3	25	290	440	0		0	0	0	120	220	100

Inputs for Individual Stands

The ProFert *Main Sheet* (shown in Figure 2 and Figure 4) includes inputs and outputs for each site analysed. After the background growth, yield and economic data is loaded through the *Load data* button, the user inputs the age, nutrient status and harvesting and fertiliser regime for each site into the *Main sheet*. The required information varies depending on the company and on whether site specific or regional plantation information is entered during the *Load data* procedures.

The inputs to the *Main sheet* are explained in the following sections include:

- Stand Information;
- Fertiliser Response parameters;
- Fertiliser Regimes; and
- Harvesting Regimes.

Stand Information

The stand information that is required varies depending on the mode being run (Regional verses Site Specific data) and the company using the model. Inputs for each mode and different companies are explained below:

- *ID*: a unique number set for each site by ProFert;
- *Site Name:* a name for each site specified by the user
- *Data file*: name of external file with growth and yield information (Site Specific mode for TPPL and HVP only);
- *Location*: geographic location of the site for calculating haulage cost;
- *Crop Type*: index of productivity and stocking used to predict growth, harvest regime and yield by Norske Skog (Norske Skog version only);
- *Site quality/Site index*: index of site productivity used to predict growth (Regional mode only);
- *Current age*: current age of stand;
- *Current stocking*: current stocking of stand;
- *Assessed volume*: stand age, standing volume and total harvested volume from the most recent assessment (Regional mode only);
- *Clearfell age*: age at which the stand is expected to be clearfelled; and

- *Discount rate*: rate that future costs and revenue are to be discounted when calculating NPV.

Note that when running ProFert in Site Specific mode, information on a site's location, current age and current stocking are input automatically from the site information loaded from the external file. However, these data can be overridden if the user inputs other values for location, current age or stocking.

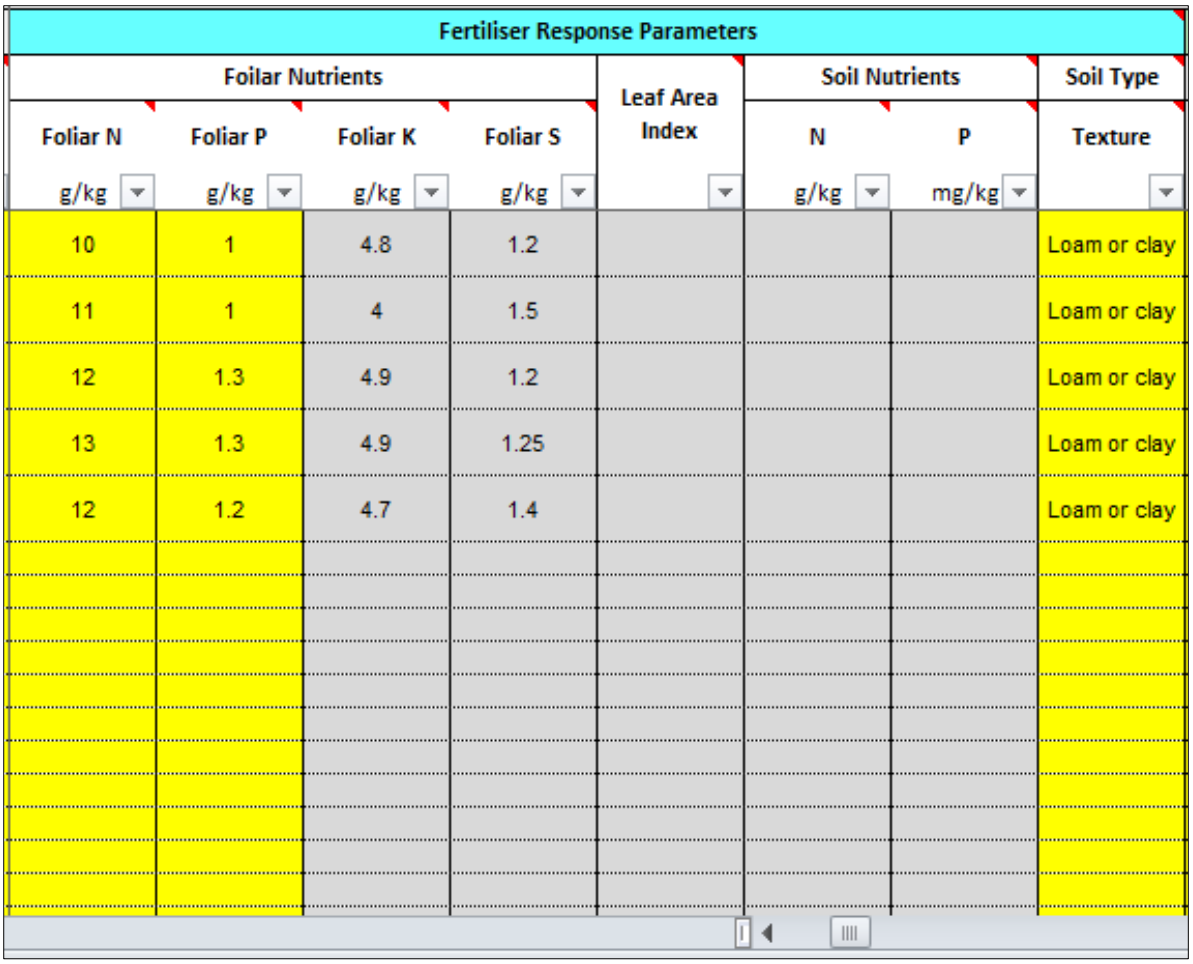
When estimating stand growth while in Regional Data mode, ProFert can either use the Site Quality value input by the user or, it can estimate the actual Site Quality if the assessed standing and harvested volume has been provided by the user. When the model is run, ProFert prompts the user to select which of these options to use. If the user selects to estimate Site Quality from assessed standing and harvested volume, ProFert will estimate actual Site Quality from the nearest two Site Qualities having higher or lower total volumes at that same age by linear interpolation. Note, that if the stand has been thinned, total harvested volume must also be included in the input sheet otherwise future growth rate may be underestimated

Fertiliser Response parameters

Primary fertiliser responses

Fertiliser response parameters used by ProFert to predict response to fertiliser are shown in Figure 12 and include:

- *Foliar nutrients*: concentrations of N, P, K and S from youngest fully developed needled collected from the upper crown of trees in mg/g;
- *Leaf area index* (TPPL version only);
- *Foliar P deficiency status* (TPPL version only);
- *Soil N and P* (TPPL version only);
- *Soil Type*: sand or clay/loam.



Fertiliser Response Parameters							
Foilar Nutrients				Leaf Area Index	Soil Nutrients		Soil Type
Foliar N	Foliar P	Foliar K	Foliar S		N	P	Texture
g/kg	g/kg	g/kg	g/kg		g/kg	mg/kg	
10	1	4.8	1.2				Loam or clay
11	1	4	1.5				Loam or clay
12	1.3	4.9	1.2				Loam or clay
13	1.3	4.9	1.25				Loam or clay
12	1.2	4.7	1.4				Loam or clay

Figure 12: Fertiliser response parameters shown in TPPL version of ProFert.

Responses to N, P and K fertiliser are predicted from relationships between foliar N, P and K responses to N, P and K based on results from fertiliser experiments in the Green Triangle and Victoria (May et al. 2005, Hopmans 2013, Raupach and Hall 1963, Hall and Raupach 1974). These relationships indicated that, in the absence of other limitations, there are relatively strong correlations between responses to fertiliser and foliar nutrients. However, the relationships for predicting responses to N and P fertiliser appear to differ with soil type or region with stands on clay-loam soils (i.e. the dataset from Victorian experiments) generally more responsive to fertiliser than those on sandy soils (i.e. the dataset from Green Triangle experiments).

The lines of best fit and confidence limits for these relationships can be viewed by clicking on the button ***Response Charts*****.** This brings up the menu shown in Figure 13. From the menu, the user can select which relationship to view for each nutrient and soil type being considered (e.g. Figure 14).

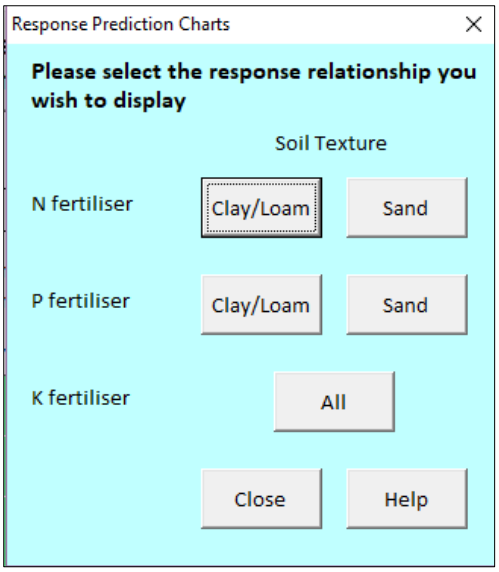


Figure 13: Menu for selecting response prediction relationships to view.

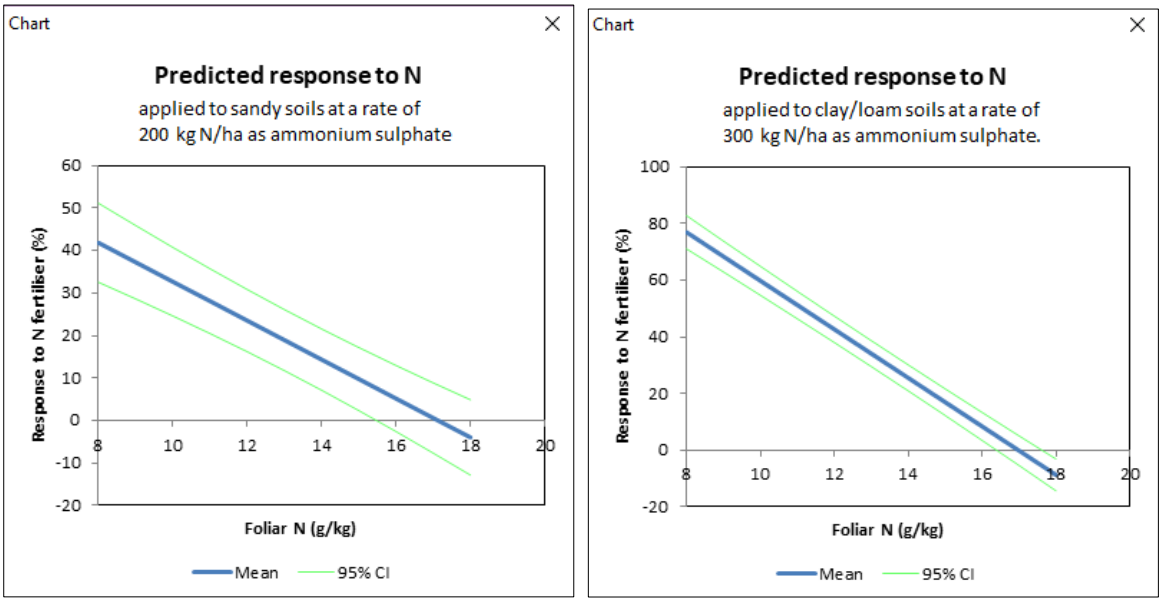


Figure 14: Examples of relationships, including 95% confidence limits, used to predict responses to N fertiliser from foliar N on a) sandy soils and b) clay-loam soils.

Additional relationships

The most reliable parameters for predicting response to fertiliser (i.e. those with relationships with the lowest uncertainty) are foliar N, P and K. However, relationships have also been developed with other parameters, based on results from the Green Triangle. In ProFert, these other parameters are used as predictors of foliar N and P concentrations, enabling ProFert to be used where no foliar data is available. These relationships have not been tested outside the Green Triangle and so have been included in the TPPL version of the model only.

The surrogate parameters include:

- Leaf area index: used to predict foliar N and P concentrations;
- Foliar P deficiency Index (based on visual assessment): used to predict foliar P concentrations;
- Soil N: used to predict foliar N;
- Soil P: used to predict foliar P;

The reliability of these relationships is lower than those based on foliar nutrient analysis. Where possible, the latter should be used in preference.

Accounting for secondary nutrient deficiencies

The relationships for predicting responses to N, P and K fertiliser are adjusted to account for deficiencies in secondary nutrients (N, P, K and S). For example, the response to N is moderated by foliar P and K concentrations and N: S ratios. Where all secondary nutrients are above optimum (as defined by Robinson and Reuter, 1997) it is assumed to that there is no limitation to response. However, where a secondary nutrient is below optimum, the response to the primary nutrient is reduced linearly with decreasing concentration of the secondary nutrient (Figure 15).

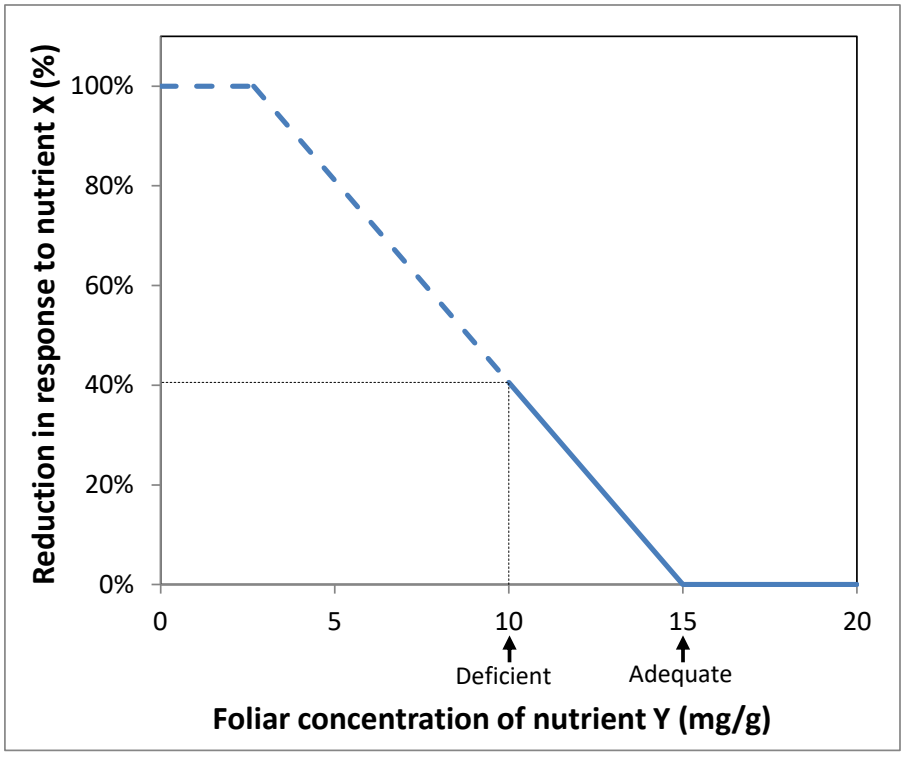


Figure 15: Illustration of the model used in ProFert to account for the effect of deficiency in a secondary nutrient (Y) on the response to a primary nutrient X.

Where a secondary nutrient is at the concentration classed as deficient, it is assumed that the response to the primary nutrient is halved. Where more than one nutrient is sub-optimal, the degree of limitation is based on the most deficient nutrient. Secondary nutrients applied at optimum rates in fertiliser are assumed to be at optimum levels.

Accounting for variation in fertiliser rate and form

The response to fertiliser is also adjusted to account for the amount and type of fertiliser applied. Optimum rates and types of fertiliser are based on those used in field experiments and are:

- 300 kg N/ha on loam or clay soils and 200 kg N/ha on sandy soils as ammonium-based N fertiliser;
- 80 kg P/ha as phosphate-based P fertiliser;
- 350 kg K/ha as potassium chloride or potassium sulphate; and
- 220 kg S/ha as sulphate.

Where the rate of application differs from the optimum, the response is increased or decreased by the proportion based on relationships between relative response and rate of application as shown in Figure 16. If N is applied as urea alone, the response is assumed to be reduced as a result of N volatilisation losses with the reduction depending on the rate of application (Figure 16a). Where P is applied together with urea, it is assumed that volatilisation losses are minimal and that there is no reduction in N response.

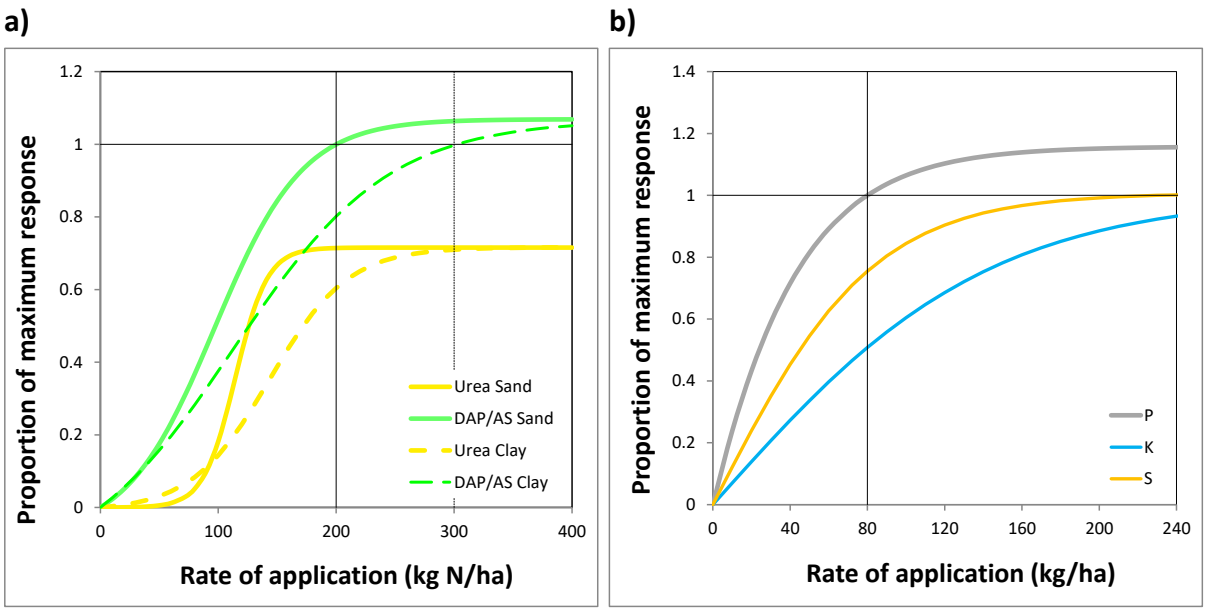


Figure 16: Relationships between relative reduction in response and rate and form of fertiliser applied and soil type showing the effects of a) N form, rate and soil type.

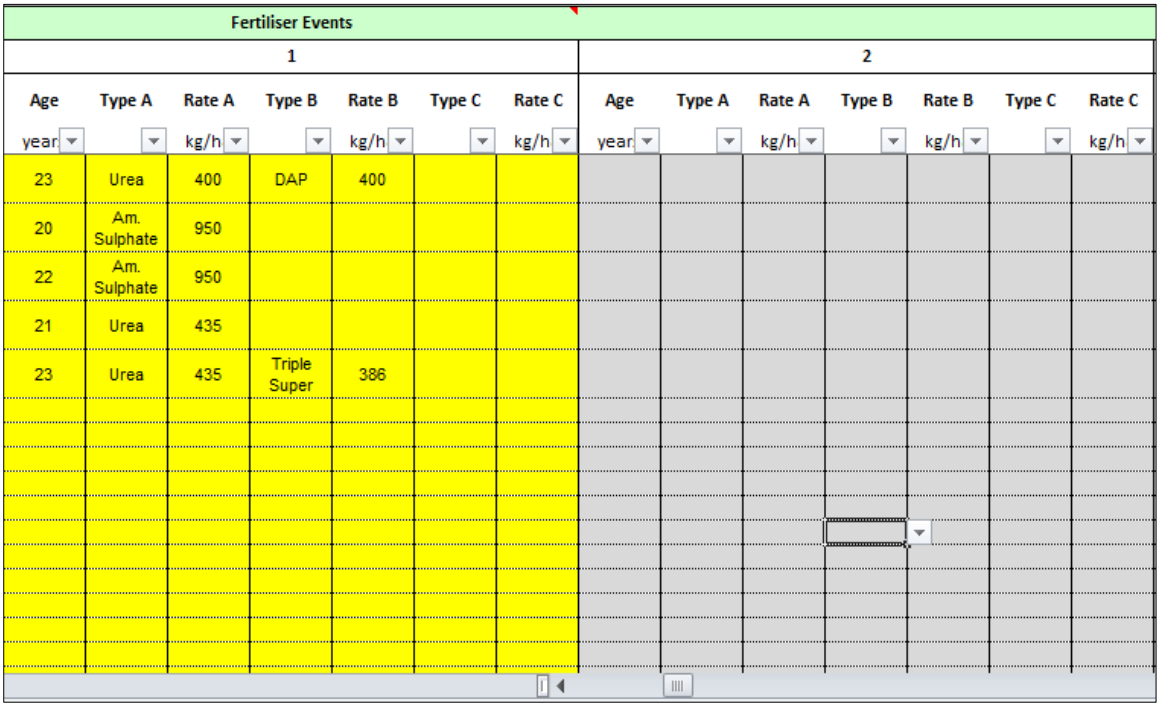
All growth limitations associated with nutrients applied as fertiliser are assumed to be corrected provided the optimum rate is used. However, if the rate of a particular nutrient applied is below optimum (or a different form of N is used) the reduction in deficiency is proportional to the reduction in response relative to the optimum based on the relationships shown in Figure 16.

Uncertainties in the predicted responses are calculated based on the uncertainties (as indicated by standard errors) in the original relationships. These uncertainties are propagated through the model to the final results to provide an indication of the final predicted growth and economic responses.

Fertiliser Regimes

Up to four fertiliser applications, each with up to three different fertiliser types and rates can be specified in on the *Main sheet* in ProFert (Figure 17). The user must enter the stand age, fertiliser type and rate for at least one future fertiliser event. Past fertiliser applications have no effect on the model as any change in stand nutrient status is assumed to be reflected in foliar nutrients.

When a cell in a fertiliser type column (i.e. Type A, Type B or Type C) is selected, a drop-down menu appears from which a fertiliser type can be selected. This menu is based on the fertiliser types entered in the sheet *Fertiliser costs.* The amounts applied are in total kg of fertiliser.



Fertiliser Events													
1							2						
Age	Type A	Rate A	Type B	Rate B	Type C	Rate C	Age	Type A	Rate A	Type B	Rate B	Type C	Rate C
year		kg/h		kg/h		kg/h	year		kg/h		kg/h		kg/h
23	Urea	400	DAP	400									
20	Am. Sulphate	950											
22	Am. Sulphate	950											
21	Urea	435											
23	Urea	435	Triple Super	386									

Figure 17: ProFert Main sheet - fertiliser regimes.

Fertiliser Rate Calculator

Located above the fertiliser response parameters section on the main sheet is a button labelled C*alculate fertiliser rate.* The calculator allows the user to readily convert between total and elemental rates of fertiliser to work out the appropriate rate to specify. For example, if the user knows that 100 kg N/h needs to be applied as di-ammonium sulphate, the calculator will provide the equivalent total amount of di-ammonium sulphate required (556 kg/ha, Figure 18). This value can then be entered into the Fertiliser regime for the site on the *Main Sheet*. Alternatively, if the user wishes to calculate the effective rate of N application if a certain total weight of fertiliser is applied, they click the button switching to Total rate -> Elemental rate and enter the total amount of fertiliser being applied.

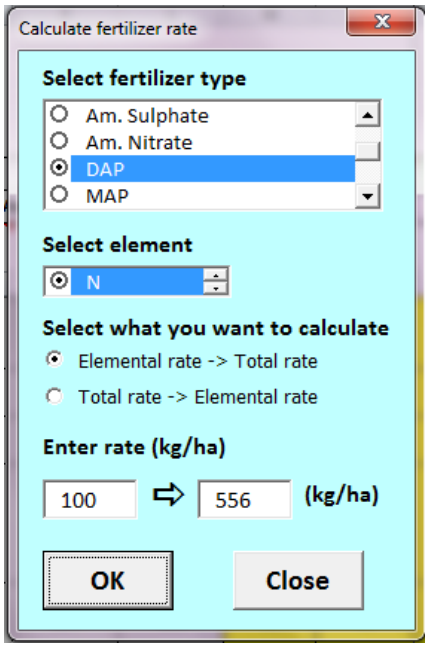


Figure 18: Fertiliser rate calculator displayed when the button labelled *Calculate fertiliser rate* is pressed.

Harvesting Regimes

Harvesting regimes include all future thinning operations prior to final harvest. When running ProFert in *Regional Data* mode, the proposed harvesting regime for each site must be entered manually into the *Main Sheet*. When running *Site Specific Data* mode, the timing and intensity of thinning operations are contained in the external growth and yield files (or, in the case of Norske Skog, stored in ProFert). However, the user can override this information by entering the timing and intensity of thinning operations into the *Main Sheet*.

Required inputs for the harvesting regime include (Figure 19):

- Age: Stand age at harvest;
- Residual stocking: stocking after thinning;
- Residual volume: the retained volume after thinning expressed as either total m^3/ha or % of original volume remaining; and
- Commercial: whether the harvested logs are sold or left on the ground.

If both the retained volume in m^3/ha and % of residual volume are entered, ProFert ignores the former and uses % residual volume. If the *Commercial* column is left blank, ProFert assumes it is a commercial thinning.

Harvesting costs entered into the sheet ***Harvesting costs*** for each thinning are assumed to correspond to the Thinning number. For example, the first harvesting and first haulage cost entered into the *Harvesting cost* sheet are assumed to apply to the first thinning (Thin1), the second harvesting and second haulage cost are assumed to apply the second thinning (Thin2) and so on. If a one thinning is left blank, then it is assumed that that thinning number is skipped and the costs for the next thinning are applied. Therefore, where a stand has already had a 1st or 2nd thinning, these columns should be left blank and information on future operations should be entered into subsequent thinnings.

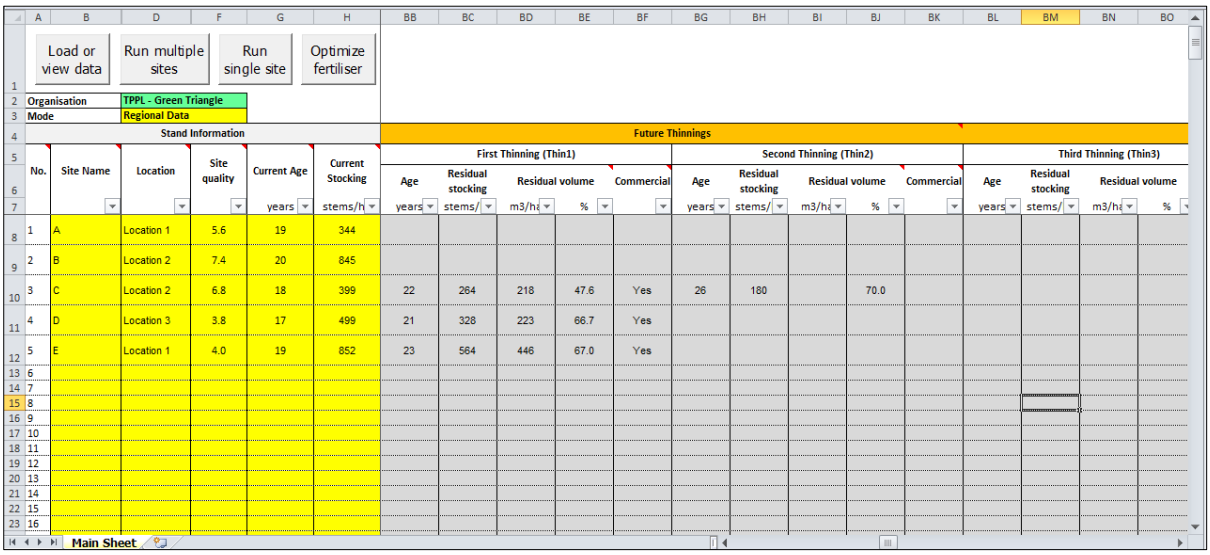


Figure 19: ProFert Main sheet - harvesting regimes.

ProFert Outputs

Multiple Site Analysis

ProFert can predict growth responses to and assess profitability of fertilising each of up to 100 stands per run using the *Run Multiple Sites* button on the *Main Sheet.*

Prior to running ProFert, check that all required data is entered using the *Load Data* button and make sure the required *Stand Information*, *Fertiliser Response Parameters*, *Fertiliser Events* and *Future Thinnings* have been entered into the *Main Sheet*. Once all required data has been entered, the *Run multiple sites* button brings up the screen shown in Figure 20.

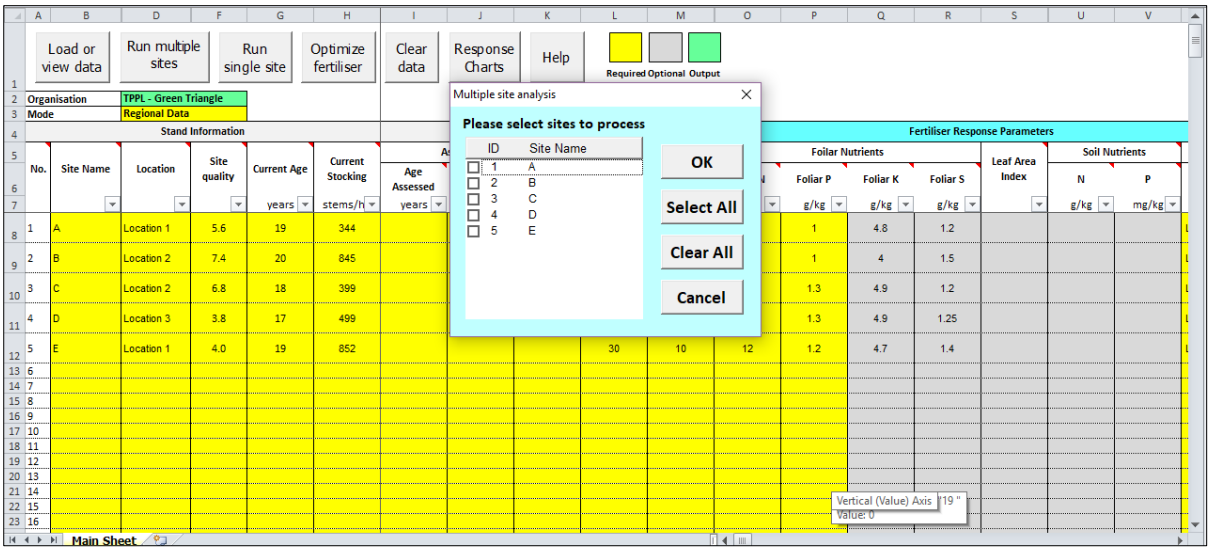


Figure 20: Multiple site selection pane.

This screen includes the names of all the sites in the table. Click on the names of sites which you want to analyse. If all sites are to be analysed you can click the button labelled *Select All*. To unselect all sites, click the *Clear All* button. To cancel the run click *Cancel.* After the required sites have been selected press *OK.*

The progress of the run is displayed in a progress bar in the centre of the screen. If there are errors or anomalies in the input data for any site, ProFert will alert the user and enter a comment in the comment column on the *Main sheet*. Depending on the error, ProFert may prompt the user to enter new data or may cancel the run.

At the end of the run a *Run completed successfully* message is shown and ProFert displays the outputs for the sites analysed (Figure 21). All output from running ProFert for multiple sites is contained on the *Main Sheet.* Outputs include:

- Predicted base responses to different nutrients;
- Total volume of the control vs. the fertilised stand;
- Increase in wood harvested at thinning and clearfell;
- Economics of fertiliser use; and
- Comments about the run.

The user can scroll through the table using the vertical and horizontal scroll bars or the results can be filtered using the buttons along the top.

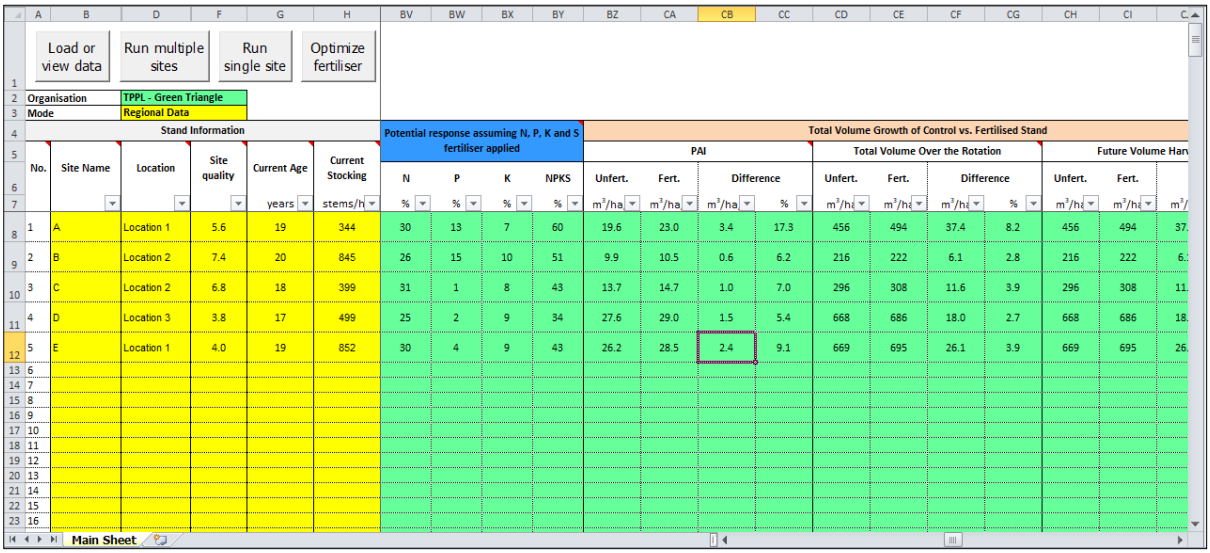


Figure 21: ProFert *Main sheet* display at run completion showing Predicted base response and Total volume growth of control vs. fertilised stand.

Predicted base responses

Predicted base responses include the estimated responses to N, P, K applied individually and NPKS applied together assuming optimum rates and forms of fertiliser are used (Figure 21). Most responses are the cumulative average over 4 years except for P applied to clay-loam soils (average over 6 years) and K (average over 21 months). The predictions are based on the relationships described in the section ***Fertiliser Response parameters***. The outputs are the theoretical cumulative responses to fertiliser after adjusting for secondary nutrient limitations.

To predict the response to fertiliser, these base responses are modified by factors including:

- the amount of each nutrient applied;
- the form of fertiliser used;
- the response period until harvest; and
- multiple future fertiliser applications.

The methods ProFert uses to account for these variables are explained in the section *Fertiliser Response parameters* and in the Main Report (May *et al.* 2017).

Total Volume Growth of Control vs. Fertilised Stand

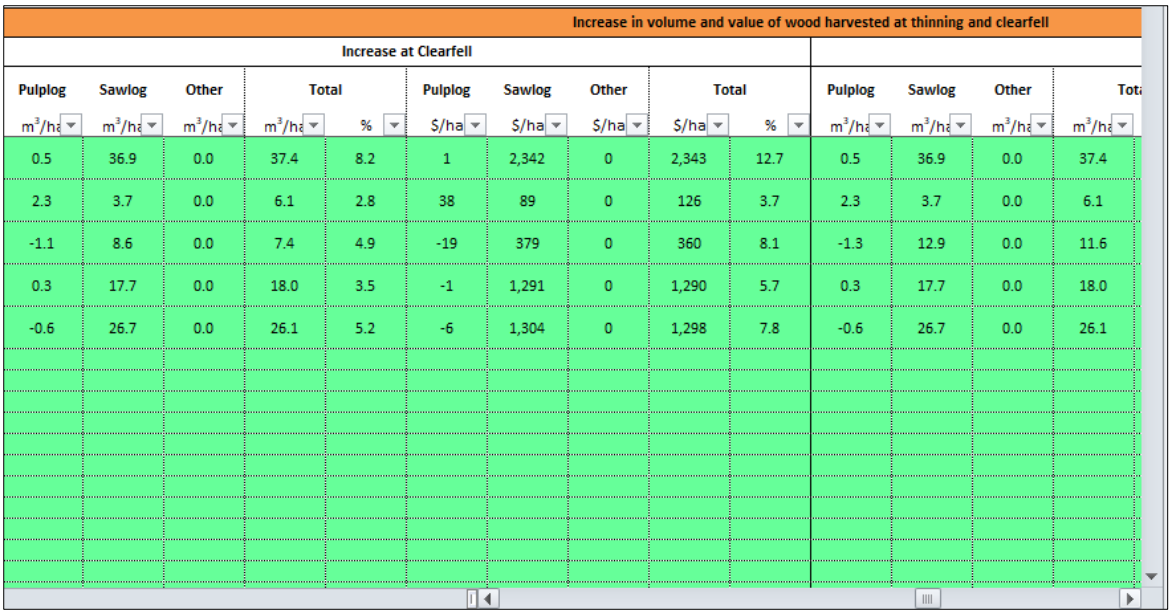
The information in the section labelled Total volume growth of Control vs. Fertilised Stand (Figure 21) includes:

- *PAI* (Periodic Annual Increment);
- *Total Volume Produced Over Rotation* (where data on previous harvests is available); and
- *Future Volume Harvested* from the stand to time of clearfell (Figure 21).

For each of the above, ProFert calculates the growth of the control, the growth of the fertilised stand and the absolute (m^3/ha) and relative (%) difference between them. *Note that, when comparing responses predicted by ProFert with actual measured increases in volume growth of fertilised plots relative to controls, the results under PAI should be used.*

Increase in volume and value of wood harvested commercially

Outputs from ProFert include the increase in volume and value of wood harvested during thinnings and clearfell (Figure 22). Products are divided into pulplogs, sawlogs and other logs as specified by the user in the product val**ue** information (see section Product values). Both the absolute (m^3/ha and $/ha) and relative (%) increases in volume and value are calculated.



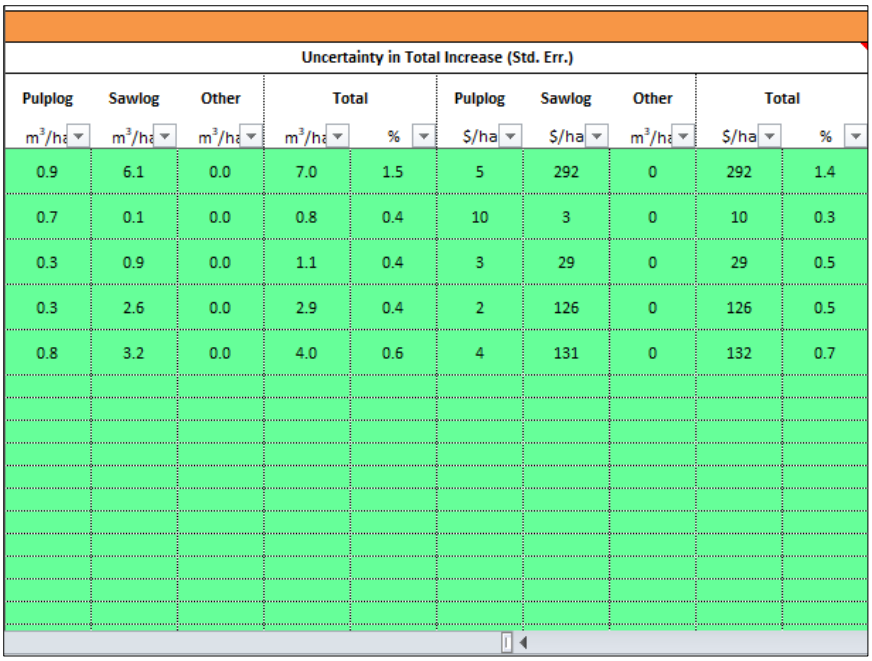
Increase in volume and value of wood harvested at thinning and clearfell													
Increase at Clearfell													
Pulplog	Sawlog	Other	Total		Pulplog	Sawlog	Other	Total		Pulplog	Sawlog	Other	Tota
m³/ha	m³/ha	m³/ha	m³/ha	%	$/ha	$/ha	$/ha	$/ha	%	m³/ha	m³/ha	m³/ha	m³/ha
0.5	36.9	0.0	37.4	8.2	1	2,342	0	2,343	12.7	0.5	36.9	0.0	37.4
2.3	3.7	0.0	6.1	2.8	38	89	0	126	3.7	2.3	3.7	0.0	6.1
-1.1	8.6	0.0	7.4	4.9	-19	379	0	360	8.1	-1.3	12.9	0.0	11.6
0.3	17.7	0.0	18.0	3.5	-1	1,291	0	1,290	5.7	0.3	17.7	0.0	18.0
-0.6	26.7	0.0	26.1	5.2	-6	1,304	0	1,298	7.8	-0.6	26.7	0.0	26.1

Figure 22: Outputs from ProFert – increases in volume and value of harvested wood products.

Uncertainties in estimates

ProFert calculates uncertainties (standard error of the mean) for the estimated increases in total volume and values of harvested products (Figure 23). These uncertainties are calculated from the standard deviations in the original relationships between fertiliser response and predictor variables. Where surrogate variables such as soil type are used instead of the original predictors the uncertainty is increased to allow for the error in estimating the predictor variables from the surrogates. Uncertainties in responses to different rates or forms of fertiliser, or years since application, are not included in the overall uncertainty estimate.

Where uncertainty data is available for the underlying stand growth, ProFert gives the user the option to include this in the final results. This provides the standard error in the total volume and value of both the control and the fertilised stand. Including this uncertainty in the underlying growth increases the uncertainty in the predicted increases in both volume and value after fertiliser application. However, it may be useful in certain situations such as where a user wishes to predict the total volume that may be harvested from a fertilised stand (rather than predict the increase in volume compared with the control).



Uncertainty in Total Increase (Std. Err.)									
Pulplog	Sawlog	Other	Total		Pulplog	Sawlog	Other	Total	
m^3/ha	m^3/ha	m^3/ha	m^3/ha	%	$/ha	$/ha	m^3/ha	$/ha	%
0.9	6.1	0.0	7.0	1.5	5	292	0	292	1.4
0.7	0.1	0.0	0.8	0.4	10	3	0	10	0.3
0.3	0.9	0.0	1.1	0.4	3	29	0	29	0.5
0.3	2.6	0.0	2.9	0.4	2	126	0	126	0.5
0.8	3.2	0.0	4.0	0.6	4	131	0	132	0.7

Figure 23: Outputs from ProFert – uncertainty in estimated volume and value of wood harvested.

Economics

Economic outputs include the predicted increase in revenue and cost of fertiliser (expressed in terms of both nominal value and discounted current value) the additional wood volume per dollar spent on fertiliser (unit wood cost), NPV (net present value) and IRR (internal rate of return, Figure 24). In addition, the uncertainty in unit wood cost and NPV is calculated. The discount rate applied to fertiliser cost and NPV is specified by the user in the *Main Sheet* (Column M).

Economics									Comment
Revenue increase		Fertiliser cost		Wood vol. per $		NPV		IRR	
Nominal	Discounted	Nominal	Discounted	Total	Std. Err.	Total	Std. Err.		
$/ha	$/ha	$/ha	$/ha	m^3/$1(	m^3/$1(	$/ha	+/- $/h	%	
2,343	821	584	399	9.38	1.77	422	104	22	Response is limited by foliar N+P+K. To maximize fertilis applied.
126	49	618	618	0.98	0.13	-569	5	-14.7	Response is limited by foliar N+P+K. To maximize fertilis applied.
456	160	618	422	2.74	0.27	-262	10	-4.1	Response is limited by foliar N+P+K. To maximize fertilis applied.
1,290	411	287	196	9.16	1.48	215	41	20.7	Response is limited by foliar N+P+K. To maximize fertilis applied.
1,298	455	615	420	6.21	0.96	35	48	11.3	Response is limited by foliar N+P+K. To maximize fertilis applied.

Figure 24: Outputs from ProFert – Economic analysis of fertiliser use and comments.

Comments and errors

ProFert provides comments on nutrients that may limit growth as well as any issues with input data for each site (Figure 24). Any nutrients that are below optimum concentrations are noted, even if they are included in fertiliser treatments, to alert the user to possible secondary limitations on the response to fertiliser. If there are problems with input data, or if predicted growth, tree size or foliar nutrients is outside the measured range, ProFert will alert the user and provide a comment in the relevant site. If the problem results in a critical error, ProFert will alert the user and will stop automatically.

Single Site Analysis

Running Single Site Analysis

In addition to predicting wood volume and value responses to fertiliser for multiple sites over a whole rotation, ProFert can provide more detailed information for individual sites on an annual basis. This data is output as a table and a series of charts which include uncertainty estimates.

Once all required data for a site are loaded using the *Load data* button and the required information is entered in the *Main Sheet*, the user can obtain detailed outputs for a site by pressing the button labelled *Run Single Site*. This button opens a menu shown from which the user can selects a site they wish to analyse (Figure 25). ProFert then calculates the growth response for the selected site and opens the *Annual Output* sheet.

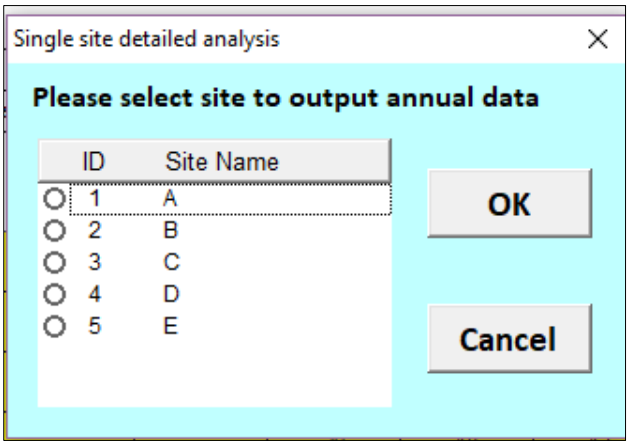


Figure 25: Single Site analysis menu.

Annual outputs – tabular data

The *Annual Output* sheet includes the site name (at the top) four buttons (to re-run the single site analysis, return to the *Main Sheet*, show charts or close the *Annual Outputs* and *Annual Charts* sheets) summary results for the site (in the green box at the top) and more detailed results below (Figure 26).

Site 4: D

Run single site | Return to Main Sheet | Show charts | Close

Site Inde: 3.8 | Vol. Incr. 18.0 m³/ha | Comment: Response is limited by foliar N+P+K. To maximize fertiliser response, these nut should be applied.
PAI Contr 27.6 m³/ha/y | NPV 215 $/ha
PAI Resp. 5.4 % | Disc. Rate 10 %

Age	Stems		Control																
	Standing	Removed	Standing				Harvested				Cumulative Harvest				Total				
			Sawlog	Pulplog	Other	Total	Sawlog	Pulplog	Other	Total	Sawlog	Pulplog	Other	Total	Sawlog	Pulplog	Other	Total	Sawlog
years	stems/ha	stems/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha	m³/ha
17	499	0	222.6	114.7	0	337.3									222.6	114.7	0	337.3	222.6
18	497	0	258.5	108.9	0	367.4	0	0	0	0	0	0	0	0	258.5	108.9	0	367.4	258.5
19	494	0	290.8	106.3	0	397.2	0	0	0	0	0	0	0	0	290.8	106.3	0	397.2	290.8
20	492	0	324.5	102.0	0	426.5	0	0	0	0	0	0	0	0	324.5	102.0	0	426.5	324.5
21	328	161	238.0	65.9	0	303.8	119.3	32.3	0	151.6	119.3	32.3	0	151.6	357.3	98.1	0	455.4	238.0
22	326	0	267.7	64.6	0	332.3	0	0	0	0	119.3	32.3	0	151.6	386.9	96.9	0	483.8	271.9
23	325	0	297.5	62.6	0	360.2	0	0	0	0	119.3	32.3	0	151.6	416.8	94.9	0	511.7	308.5
24	323	0	324.7	62.8	0	387.5	0	0	0	0	119.3	32.3	0	151.6	444.0	95.1	0	539.1	342.5
25	321	0	351.9	62.5	0	414.4	0	0	0	0	119.3	32.3	0	151.6	471.2	94.8	0	565.9	373.2
26	320	0	377.8	62.8	0	440.7	0	0	0	0	119.3	32.3	0	151.6	497.1	95.1	0	592.2	400.8
27	318	0	403.6	62.9	0	466.4	0	0	0	0	119.3	32.3	0	151.6	522.8	95.1	0	618.0	425.7
28	317	0	428.6	63.0	0	491.6	0	0	0	0	119.3	32.3	0	151.6	547.9	95.3	0	643.2	448.8

Main Sheet | Annual Outputs | Annual Charts

Figure 26: Annual outputs – summary information and growth of unfertilised stand.

The table contains annual results for the control (unfertilised stand, shown in brown), the fertilised stand (shown in green) and the absolute and percentage increase in growth and profitability (shown in blue). These results include:

- Total Volume of the Stand (m^3/ha):
    - Control: standing, harvested, cumulative harvest and total;
    - Fertilised: standing, harvested, cumulative harvest and total;
    - Difference: standing, harvested, cumulative harvest and total;
- Volume Growth (m^3/ha/y):
    - Control: CAI and PAI;
    - Fertilised: CAI and PAI;
    - Fertiliser response: CAI and PAI in both m^3/ha/y and % increase;
- Volume of Individual Trees m^3/tree:
    - Control: Standing and harvested;
    - Fertilised: standing and harvested;
    - Difference: standing and harvested;

- Unit wood value ($/m^3):
    - Control: standing and harvested;
    - Fertilised: standing and harvested;
    - Difference: standing and harvested;
- Stand value ($/ha):
    - Control: standing and harvested;
    - Fertilised: standing and harvested;
    - Difference: standing and harvested;
- Economics:
    - Increase in value of harvested products (annual and cumulative nominal increase in value);
    - Fertiliser cost (nominal annual and cumulative cost);
    - Profit (annual and cumulative nominal costs and revenue); and
    - NPV (difference between annual and cumulative discounted costs and revenue).

These results are further broken down by product category as follows:

- Sawlogs;
- Pulplogs; and
- Other logs.

Annual outputs – charts

In addition to the tabular data on the sheet *Annual Outputs*, results are displayed graphically on the sheet *Annual Output Charts.* At the top of the page is a menu showing the different charts that are available (Figure 27). The user can view a particular chart by simply clicking on the chart name. Clicking on the button *Return to Annual Data* takes the user back to the *Annual Outputs* sheet while the button *Return to Main Sheet* takes the user back to the Main Sheet. Pressing the Close button closes the *Annual Charts* sheet.

Examples of the various charts produced from the detailed single site analysis are shown in Figures 27, 28 and 29.

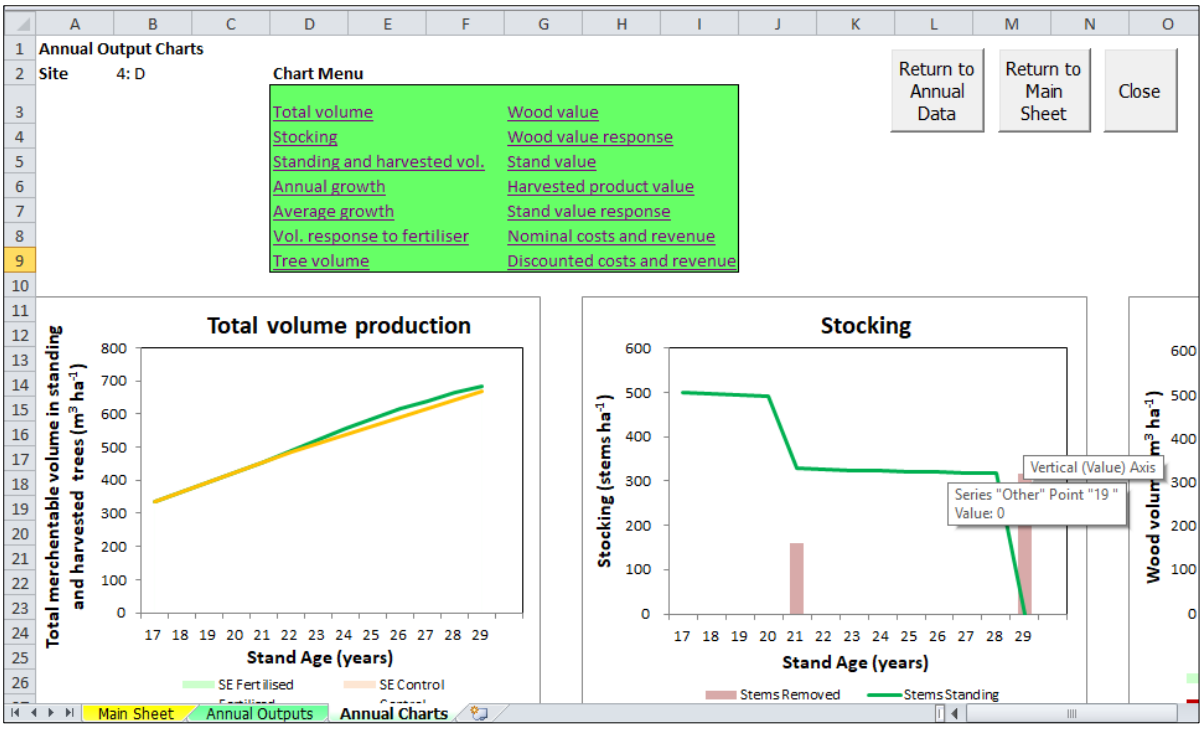


Figure 27: Annual charts sheet showing the menu for selecting charts to view from the single site analysis.

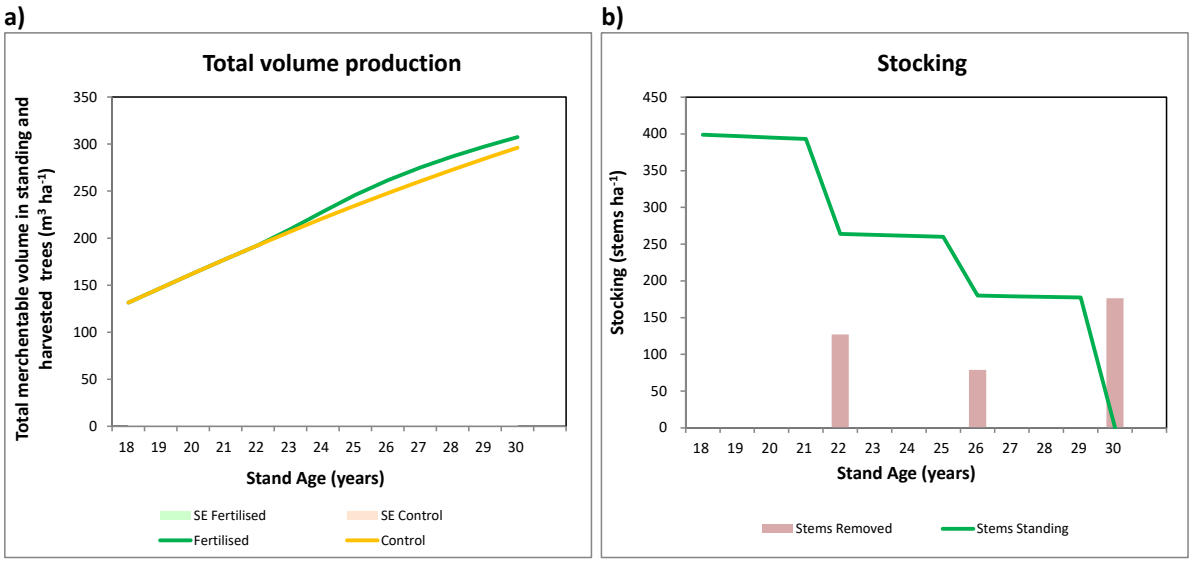


Figure 28: Chart outputs from the ProFert *Single Site* analysis showing a) total volume production and b) stocking and harvested stems.

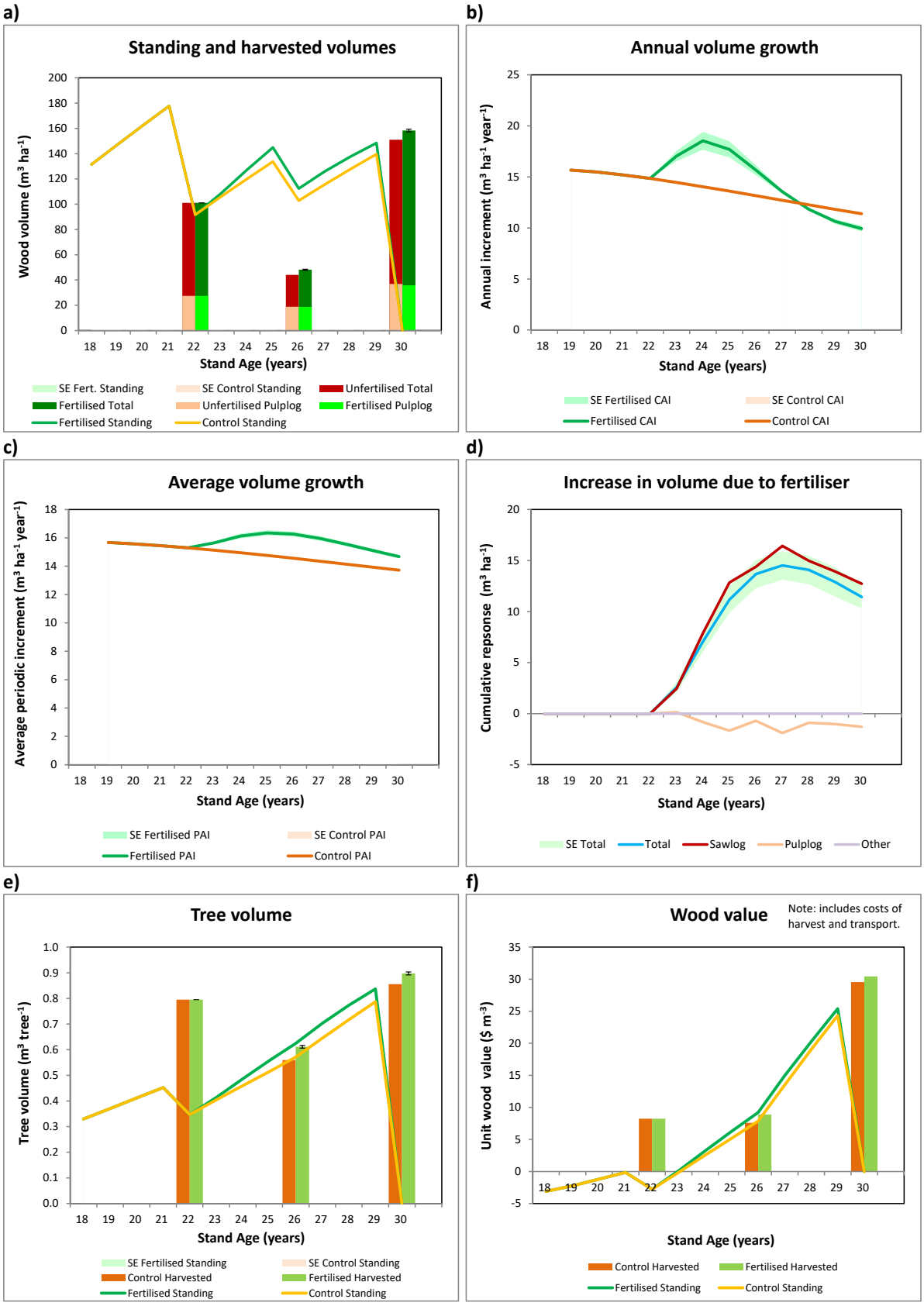


Figure 29: Chart outputs from the ProFert *Single Site* analysis showing a) standing and harvested volumes, b) annual volume growth for control and fertilised stand, c) average volume growth (PAI), d) increase in stand volume in response to fertiliser, e) average tree volume and d) average wood value.

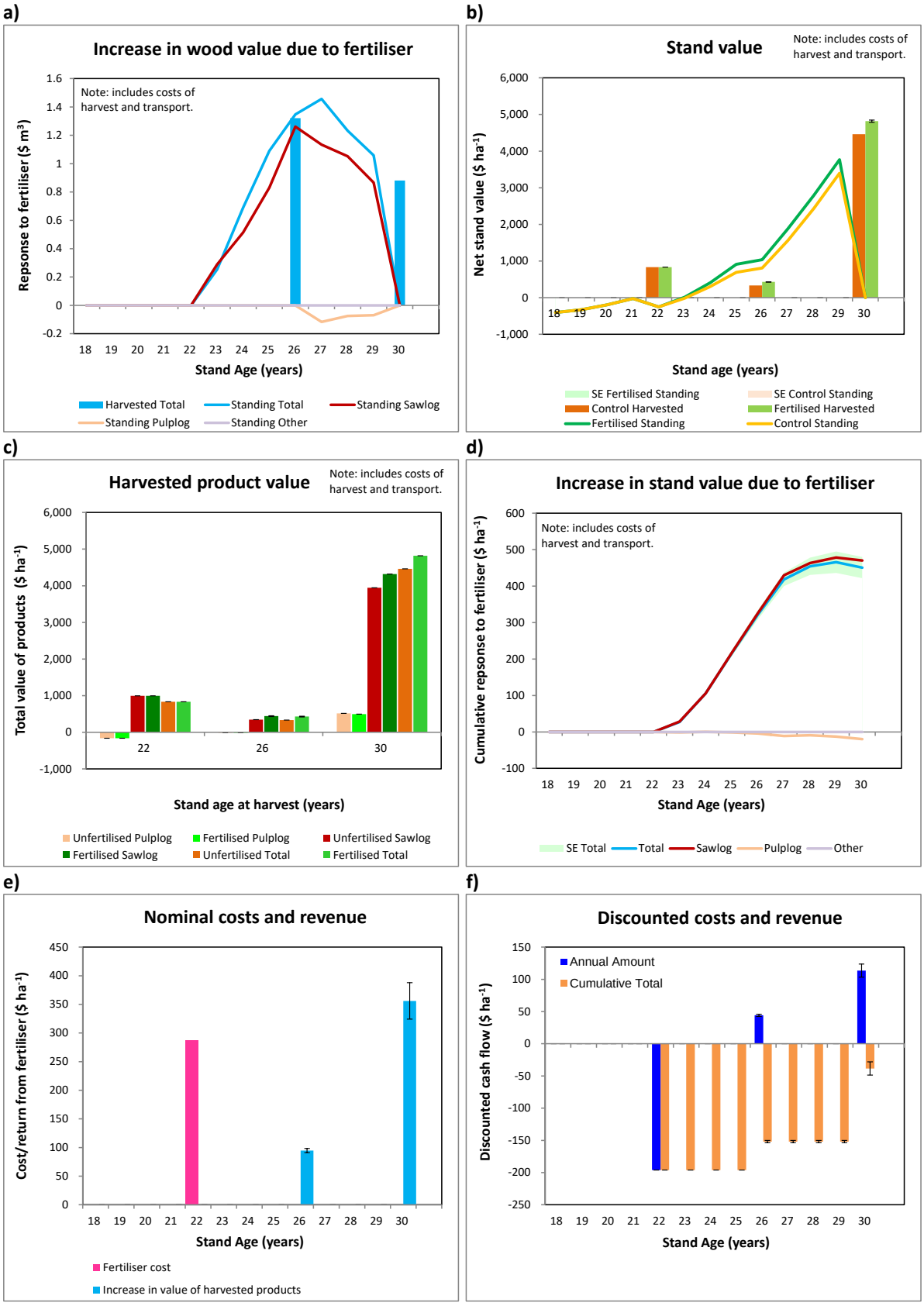


Figure 30: Chart outputs from the ProFert *Single Site* analysis showing a) increase in wood value in response to fertiliser, b) total value for standing and harvested trees, c) total value of products harvested, d) increase in stand value in response to fertiliser, e) nominal costs and revenue and f) annual and cumulative discounted costs and revenue.

Optimizing Fertiliser

Running the Optimizer

ProFert can also be used to identify the optimum amount and type of fertilizer to apply to a site for up to four future applications. Only the stand age at the time of each proposed future application and the types of fertiliser to consider need to be specified.

The fertilizer optimizer can be used once all required site data has been loaded and stand age, harvesting, response prediction parameters and proposed ages for fertiliser application have been entered into the *Main sheet*. Pressing the *Optimize Fertilizer* button opens the selection panel shown in Figure 31.

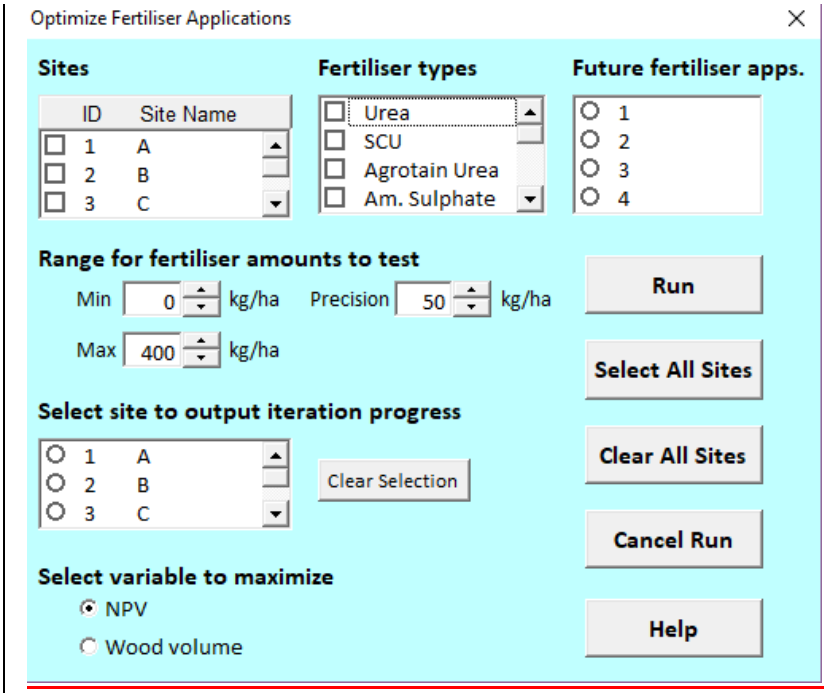


Figure 31: Panel which opens when Optimize Fertilizer button is pressed.

In this panel the user must specify:

- The names of sites to optimize;
- Fertilizer types to choose from;
- Number of future fertilizer applications;
- Variable to optimize for (NPV or wood volume per dollar spent).

In addition the user can change the range and precision of fertiliser estimates and choose to output all iterations for a single site.

- Range of amounts (kg/ha) for each fertilizer to test;
- Degree of accuracy (interval in kg/ha) in selecting quantities to apply;
- Name of site to output iteration results for (optional).

The number of iterations increases exponentially with the numbers of different fertilizer types, applications and amounts to test. Therefore, care must be exercised if testing more than 3 different types or 3 different applications. Otherwise the optimization process can take a long time to complete. During optimization, ProFert shows the progress for each site and the overall run (Figure 32). If the optimization is taking longer than expected, it can be cancelled anytime by pressing the *Cancel Run* button.

If fertilizer rates or types are entered manually into the *Main Sheet* in the columns for Type A and Type B (the first two fertiliser types), these are overwritten during the optimization process. However, fertiliser type and rate entered into the columns for fertiliser Type C (the last fertiliser type for each application) are not changed. This allows the user to have some control over the optimisation. This function can be useful, for example where it is known that a certain nutrient (e.g. S or K) may be limiting growth and therefore will limit the response to other nutrients applied (e.g. N and P).

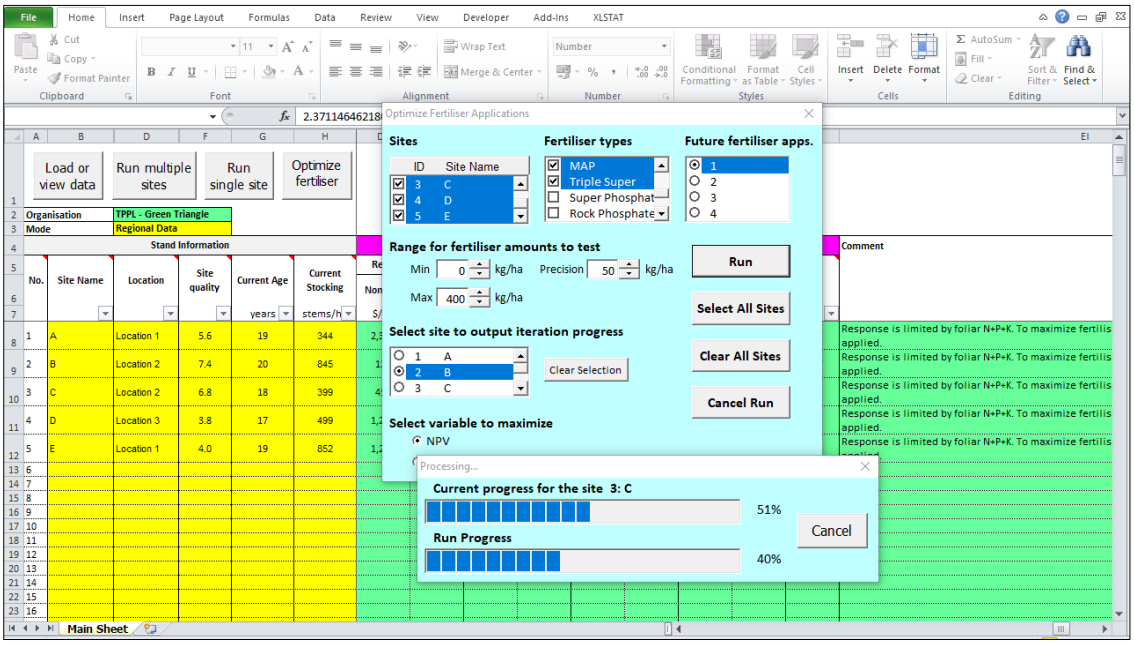


Figure 32: Display while running ProFert's fertiliser optimizer showing the options selected and the progress of the optimization procedure.

Optimization Outputs

At the end of the optimization, the most profitable fertilizer regime (or the regime that maximized wood production if selected) for each site is copied into the *Main Sheet* together with the predicted increase in wood production and financial return of the regime. If no combination from the ranges of fertiliser types and rates selected by the user is found to be profitable the fertiliser regime is left blank. Similarly, if more than one future fertiliser application is specified, then any application years for which no fertiliser combination has been found to be profitable are left blank.

In addition to outputting the optimum fertilizer regime for each site, the user can view the results of all iterations for a single site. Before running the optimizer, the user can select a site from the optimization panel by scrolling through the list of sites under the heading *Select site to output iterization progress*. During the optimization, fertiliser types, amounts and results (fertiliser cost, growth response, profitability, NPV and unit wood production) for the selected site are copied into a table in the sheet titled *Optimization* (Figure 33). Outputs for the optimum fertiliser regime are summarised at the top of the sheet. Filter buttons at the top of each column in the table can be used to filter the results to view the most profitable fertiliser combinations.

The four buttons along the top of the sheet allow the user to re-run the optimizer, display the sheet with *Optimizer Charts* for the iterations, return to the *Main sheet* or close the *Optimizer Results* sheet.

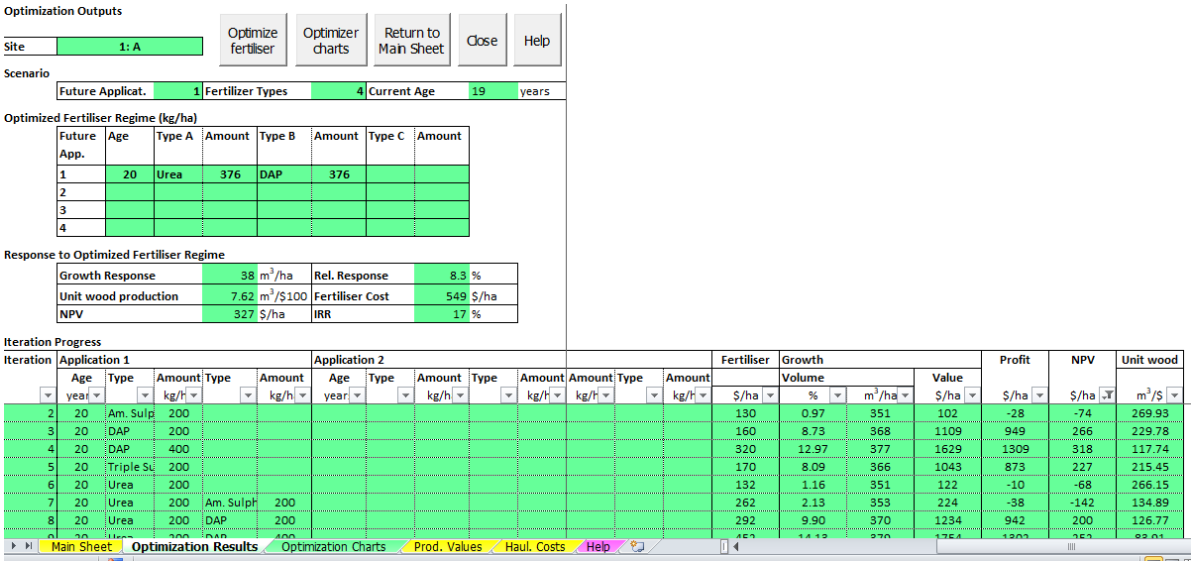


Figure 33: Results of optimization iterations for a single stand showing the iteration number, fertiliser applied.

The results in the table are also plotted on two charts in the sheet *Optimization Charts* (Figure 34). The top chart shows the total profit (nominal revenue minus costs) and NPV for each iteration. The lower chart shows the % increase in wood production and the amount of additional wood produced per dollar spent on fertiliser (discounted to current value).

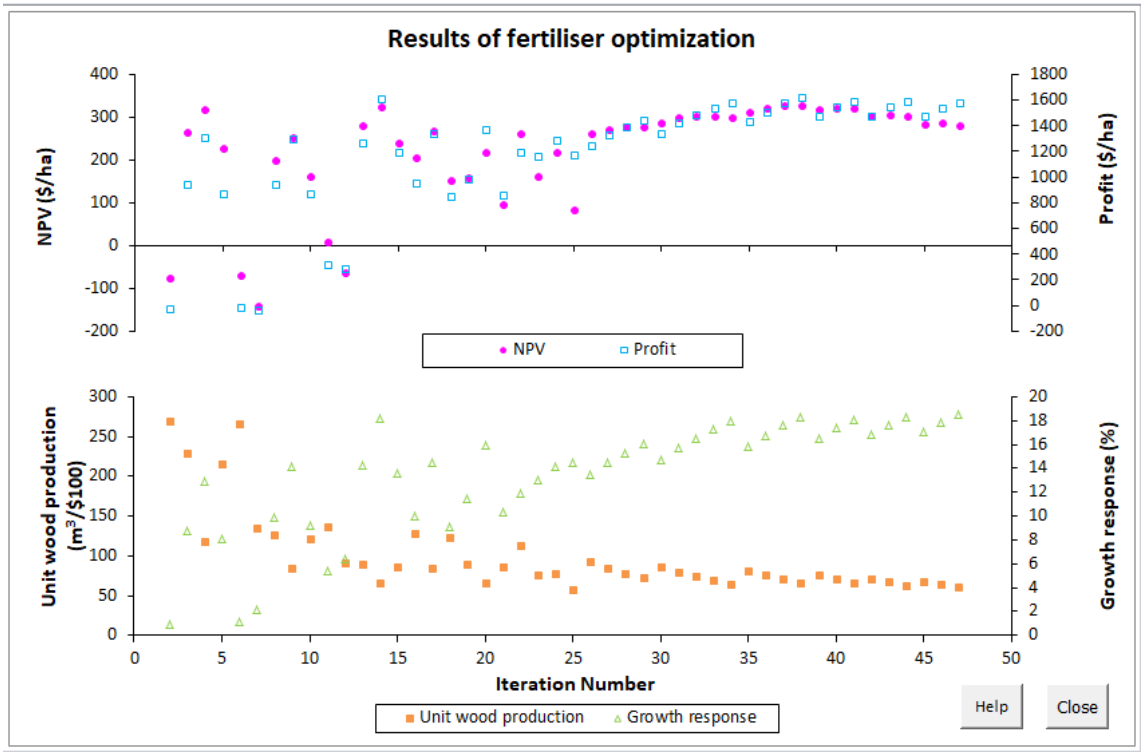


Figure 34: Charts showing the iteration results for one site including NPV and Profit (top), and unit wood production and growth response (bottom).

Clearing Data

To clear inputs or outputs from ProFert, the user can press the *Clear Data* button on the *Main Sheet.* This button displays a selection panel with four options (Figure 35):

- Stand Inputs: clears input data for all sites from the Main Sheet including all values in the yellow (mandatory) and grey (optional) columns;
- Model Outputs: clears all outputs from the *Main Sheet, Annual Outputs* and *Optimizer Iterations* sheets for all sites (values in green columns);
- *Product Values and Costs*: clears all inputs from the sheets with product values and harvesting and haulage costs;
- *Growth and Yield Data*: clears growth data and product recoveries.

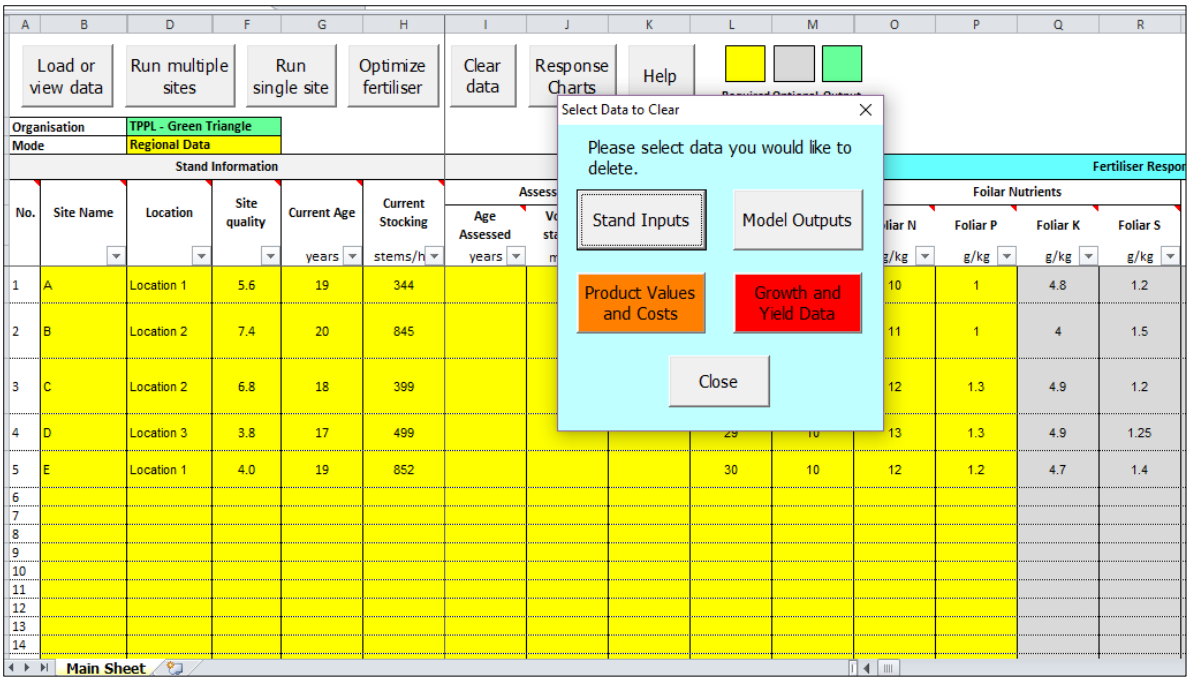


Figure 35: Selction panel displayed after the *Clear Data* button is pressed.

Note that clearing data does not remove data in external files or the references to those files in ProFert.

Help

ProFert also contains a help menu which includes a summary of the information in this user manual.

In addition to the instructions here, ProFert contains comment boxes which describe the inputs for each sheet. If an error is encountered during the run for a particular site, then a comment will appear on the screen and information relating to the error is printed in the comment box for that site.

For any other questions or assistance please contact the programmer and author of ProFert:

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References

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