5. Processor

Overview

BioSum's Processor module handles two major tasks: 1) preparing data summaries for input to OpCost (a forest operations cost simulator developed specifically for use with BioSum) and 2) summing, for each modeled silvicultural sequence, the volume, biomass, and value of wood collected from each stand at each simulation cycle where harvest occurs.

By processing FVS generated "cut lists" associated with harvest events occurring as part of a silvicultural sequence, Processor calculates a suite of cost-relevant metrics from the tree records contained in the cut list tables (generated during the FVS simulation and subsequent FVS Output Load operation in BioSum and stored in the project/fvs/data/variant_name/BioSumCalc directories) and attributes of the plot and condition (stored in project/db/master) to which the stand is linked. Cut list metrics include, for each of three user-defined harvested tree size classes (chip, small log and large log), trees per acre (tpa), tpa-weighted average volume (cubic feet) per tree, tpa and volume weighted average wood density (lbs/ft^3) per tree, percent of volume in hardwood species, percent of harvest volume in that size class that will be chipped, and, for small and large log trees, quadratic mean diameter.

Processor also calculates trees per acre and average volume per tree for brush-cut size (sub chip tree-sized) trees in the cut list and the fraction of the live tree basal area that is harvested under the prescription. For each combination of stand, silvicultural sequence (package) and FVS cycle, these summary metrics are passed as input to OpCost along, with the assumed harvest system and operation size (area in acres) and stand-level parameters such as slope, yarding distance and time required for harvest equipment to "move-in" and be ready for forest operations.

Based on these inputs, OpCost predicts harvest costs per acre, with chipping and move-in costs broken out separately, which is useful for some analyses. All inputs to and outputs from OpCost are accessible via Access databases within the OpCost directory of a BioSum project. Processor transfers appropriate results to a harvest_costs table in the processor scenario database (in the project/processor/scenario_name directory).

Processor also calculates per acre volume, weight, and value of merchantable and energy wood removed, by FVS cycle, as a result of implementing a silvicultural sequence. These are binned by user-defined diameter classes and species groups and stored in the processor scenario database's tree_vol_val_by_species_diam_groups table.

Module Components

The button that activates the Processor module can be found in the module-selector on the left side of the FIA BioSum Manager desktop (it's labeled "Processor"). Selecting it opens a 2-button panel that accesses these tasks: (1) **Tree Species**—audit the tree species table, and (2) **Start BioSum Processor's** interactive parameter specification workflow. The first 1 must complete successfully before initiating the BioSum Processor.

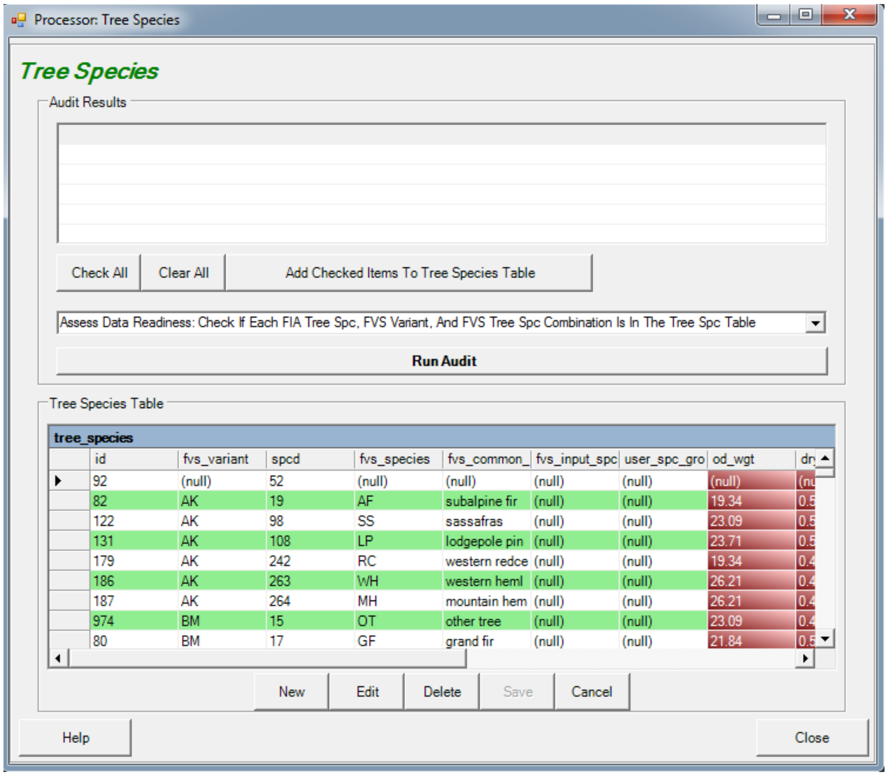
Tree Species

This button initiates a dialog for conducting audits of cut list species attributes and for managing the tree_species table stored in project\db\ref_master. As with the Tree Species task in the FVS module's work flow, the purpose of this table is to provide a systematic method for assigning FVS species codes for every FIA species code that occurs in the cut list tree data generated from FVS. These assignments can vary by FVS variant, so the table contains multiple records for most species.

Audits should be run the first time FVS cut list output is used, to assess data readiness for subsequent processes. The audit will identify any combinations of FIA tree species, FVS variant, and FVS tree species found in the FVS output that are absent from the *tree_species* table. This could happen, for example, due to regeneration provisions coded into the FVS KCP files if tree regeneration is modeled for species that do not occur in the tree_species table for that variant. To assure successful completion of the rest of the Processor module, users are advised to ensure a clean audit.

1. Click the **<Tree Species**> button in the Processor module selector panel to open the **Tree Species** window. The data displayed in the *tree_species* table in the bottom half of this window derives from a work table, generated by filtering the /db/ref_master_tree_species table based on the FIA species codes present in the /fvs/data/FVSOUT_TREE_LIST.db database file. Note that ALL records for species with matches in the FVS_CutTree table will enter this work table, regardless of the variant associated with the record in the cut list.

This table shows every combination of variant and FIA species code (spcd) and the FVS species to which it is "mapped" (fvs_species and fvs_input_spcd), and the scientific nomenclature (genus and species). Processor uses the FIA species code to assign oven dry weight (wood density) and dry to green ratio parameters from a reference table, as both are needed to estimate green weight of merchantable and energy wood for calculating costs of delivering wood from the forest to facilities.



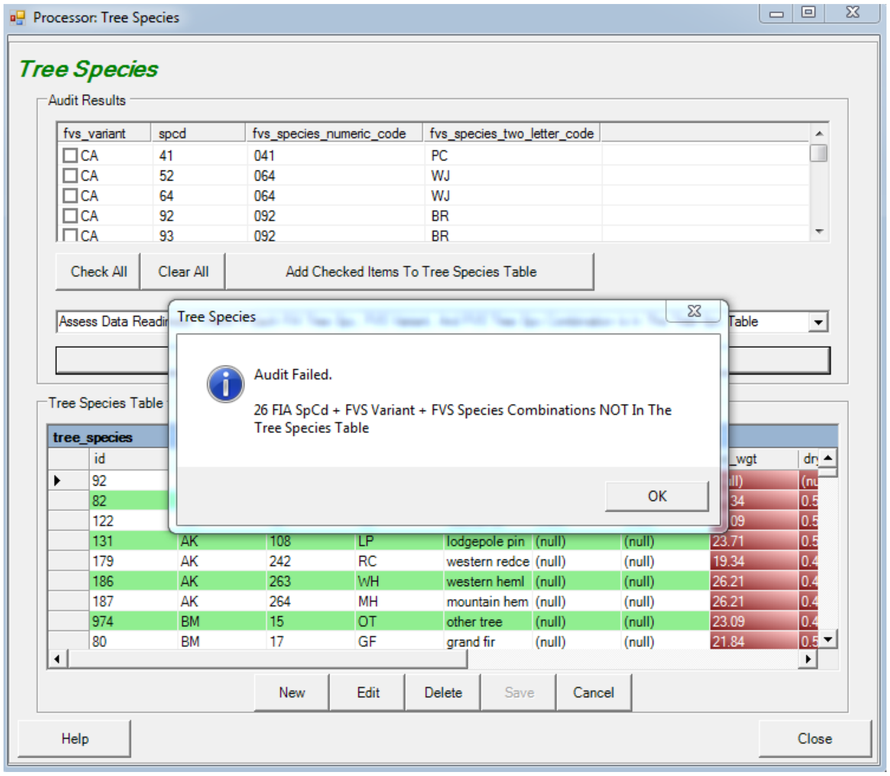
Assess Data Readiness: Check If Each FIA Tree Spc, FVS Variant, And FVS Tree Spc Combination Is In The Tree Spc Table

tree_species

id	fvs_variant	spcd	fvs_species	fvs_common_	fvs_input_spc	user_spc_gro	od_wgt	dry
92	(null)	52	(null)	(null)	(null)	(null)	(null)	(nu
82	AK	19	AF	subalpine fir	(null)	(null)	19.34	0.5
122	AK	98	SS	sassafras	(null)	(null)	23.09	0.5
131	AK	108	LP	lodgepole pin	(null)	(null)	23.71	0.5
179	AK	242	RC	western redce	(null)	(null)	19.34	0.4
186	AK	263	WH	western heml	(null)	(null)	26.21	0.4
187	AK	264	MH	mountain hem	(null)	(null)	26.21	0.4
974	BM	15	OT	other tree	(null)	(null)	23.09	0.4
80	BM	17	GF	grand fir	(null)	(null)	21.84	0.5

Figure 5.1 –Tree Species window, showing a work table derived from the *tree_species table in the lower half.*

2. In the drop down list box above the tree_species table, make sure the audit displayed is **"Check If Each FIA Tree Spc, FVS Variant, And FVS Tree Spc Combination Is In The Tree Spc Table"**), then click **<Run Audit>**. Within the FVS module completed earlier in the BioSum workflow, this audit was performed to check if each FIA tree species and FVS variant combination in project_name/db/master_tree existed in the *tree_species* table. Within Processor, this audit checks, using FVS_CutTree tables as the source, rather than the master.TREE table, to be sure that every combination of FIA tree species (as determined by the tree record in MASTER.TREE) and FVS tree species (as specified in the FVS_CutTree output) for a tree has a tree_species record for the FVS variant where that tree exists. It also checks new trees "created" during the FVS simulation based on keywords used to represent regeneration. The audit will display a message dialog reporting the number of variant/tree species combinations that are not represented in the table based on a review of FVS_CutTree trees.



fvs_variant	spcd	fvs_species_numeric_code	fvs_species_two_letter_code
□ CA	41	041	PC
□ CA	52	064	WJ
□ CA	64	064	WJ
□ CA	92	092	BR
□ CA	93	092	BR

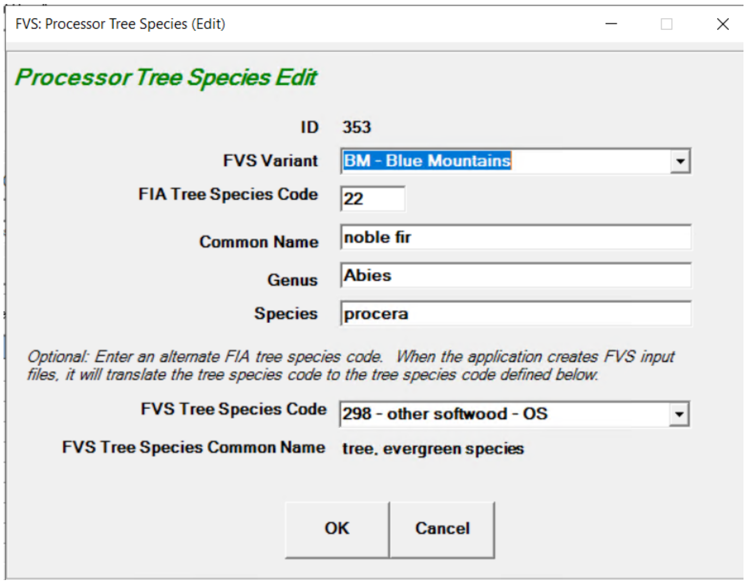
Audit Failed.

26 FIA SpCd + FVS Variant + FVS Species Combinations NOT In The Tree Species Table

id							_wgt	dr
92							ll)	(nu
82							34	0.5
122							09	0.5
131	AK	108	LP	lodgepole pin	(null)	(null)	23.71	0.5
179	AK	242	RC	western redce	(null)	(null)	19.34	0.4
186	AK	263	WH	western heml	(null)	(null)	26.21	0.4
187	AK	264	MH	mountain hem	(null)	(null)	26.21	0.4
974	BM	15	OT	other tree	(null)	(null)	23.09	0.4
80	BM	17	GF	grand fir	(null)	(null)	21.84	0.5

Figure 5.2 – Audit Failed message. Records in the Audit Results window need to be added to the tree_species table.

3. If this audit fails, results will be displayed for cases where combinations are missing from the *tree_species* table. These records can be selected (via checkboxes) for addition to the *tree_species* table individually, or en masse (by clicking **<Check All>**), followed by **<Add Checked Items To Tree Species Table>** button. Be sure to **<Save>** changes after adding records. These additions to the work table will automatically propagate through to also update *ref_master.tree_species*. **Important Note**: Due to a glitch in the audit, the audit may report a failure even if all species are in the Tree Species table. If there are no checkboxes in upper grid to check, this error message may be ignored.



FVS: Processor Tree Species (Edit)

Processor Tree Species Edit

ID 353

FVS Variant: BM - Blue Mountains

FIA Tree Species Code: 22

Common Name: noble fir

Genus: Abies

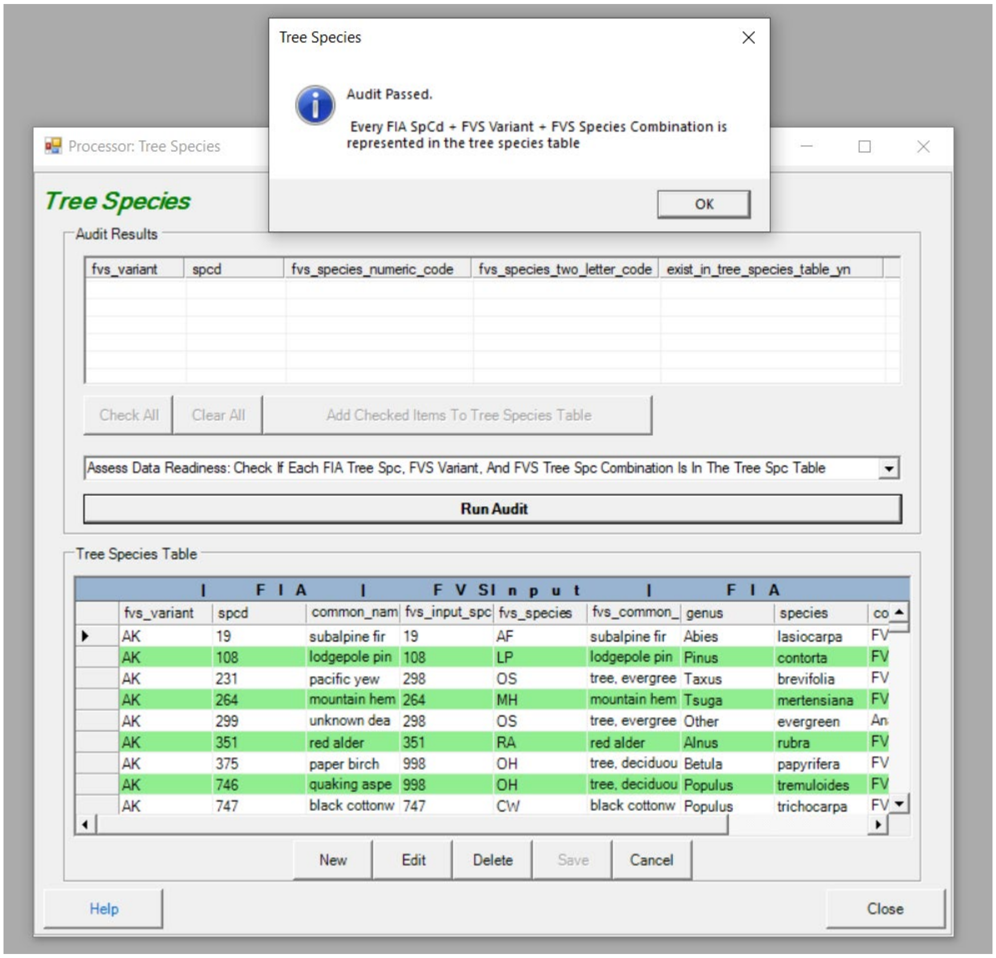
Species: procera

Optional: Enter an alternate FIA tree species code. When the application creates FVS input files, it will translate the tree species code to the tree species code defined below.

FVS Tree Species Code: 298 - other softwood - OS

FVS Tree Species Common Name: tree, evergreen species

Figure 5.3 – Tree species edit window for viewing cross-walks between FIA and FVS tree species codes; these can also be edited in the tree species table part of the Tree Species dialogue.



Tree Species

Audit Passed.

Every FIA SpCd + FVS Variant + FVS Species Combination is represented in the tree species table

Processor: Tree Species

Tree Species

Audit Results

fvs_variant	spcd	fvs_species_numeric_code	fvs_species_two_letter_code	exist_in_tree_species_table_yn

Assess Data Readiness: Check If Each FIA Tree Spc, FVS Variant, And FVS Tree Spc Combination Is In The Tree Spc Table

Tree Species Table

| F I A		| F V S I n p u t			| F I A			
fvs_variant	spcd	common_nam	fvs_input_spc	fvs_species	fvs_common_	genus	species	co
AK	19	subalpine fir	19	AF	subalpine fir	Abies	lasiocarpa	FV
AK	108	lodgepole pin	108	LP	lodgepole pin	Pinus	contorta	FV
AK	231	pacific yew	298	OS	tree, evergree	Taxus	brevifolia	FV
AK	264	mountain hem	264	MH	mountain hem	Tsuga	mertensiana	FV
AK	299	unknown dea	298	OS	tree, evergree	Other	evergreen	An
AK	351	red alder	351	RA	red alder	Alnus	rubra	FV
AK	375	paper birch	998	OH	tree, deciduou	Betula	papyrifera	FV
AK	746	quaking aspe	998	OH	tree, deciduou	Populus	tremuloides	FV
AK	747	black cottonw	747	CW	black cottonw	Populus	trichocarpa	FV

Figure 5.4 – the "Audit Passed" dialog box signifies a successful tree species audit.

4. After the audit has passed without error, **<Save>** changes and **<Close>** the Tree Species window.

OpCost

Introduction: OpCost is an R script that estimates treatment costs (dollars per acre) for each combination of stand, silvicutural sequence and treatment year as a function of these attributes, calculated in BioSum from project data that draws on plot, condition and tree attributes as well as user input:

- Percent slope
- Yarding distance
- FVS simulation year (used when applying discounting)
- Stand elevation
- Harvest system
- Chip trees per acre
- Chip trees Merchantable as a percent of Total Volume
- Chip trees average volume per tree (ft3)
- Chip trees average wood density (lbs./ft3)
- Chip trees hardwood percent
- Small log trees per acre
- Small log trees Merchantable as a percent of Total Volume
- Small log trees Chip Percent with Category 1 and 3 harvest systems
- Small log trees Chip Percent with Category 2 and 4 harvest systems
- Small log trees Chip Percent with Category 5 harvest systems
- Small log trees average volume per tree (ft3)
- Small log trees average wood density (lbs./ft3)
- Small log trees hardwood percent
- Large log trees per acre
- Large log trees Merchantable as a percent of Total Volume
- Large log trees Chip Percent with Category 1, 3 and 4 harvest systems
- Large log trees Chip Percent with Category 2 harvest systems
- Large log trees Chip Percent with Category 5 harvest systems
- Large log trees average volume per tree (ft3)
- Large log trees average wood density (lbs./ft3)
- Large log trees hardwood percent
- BrushCut (cut but not taken to landing) TPA
- BrushCut average volume per tree (ft3)
- Move-in hours (to bring each piece of logging equipment to the work site)
- Harvest area (acres) on which the silvicultural sequence is implemented
- Basal area fraction (of all live tree basal area) that is harvested
- Quadratic mean diameter of small log trees (inches)
- Quadratic mean diameter of large log trees (inches)

OpCost relies on published harvest cost models developed from empirical studies of harvest systems conducted in a variety of geographic regions with different topographies and silvicultural systems. The data from these studies, some of which date back decades, include information about the kinds and number of machines typically used for a given system, and the models developed from these data typically predict, for each machine used in a logging system, the productive machine hours (PMH) required to log, forward or yard, load and, if applicable, chip the harvested wood. Machine time requirements estimated from these models are multiplied by typical operating costs per PMH to arrive at treatment cost, and move-in times are multiplied by the hourly rental rate per machine and divided by the assumed area treated to calculate move-in costs per acre for getting all of the equipment associated with a harvest system to a treatment site and ready to begin production. The sum of treatment and move-in cost and an optionally specified set of supplemental per acre costs (for example, to account for pile and burning of activity and surface fuels) yields overall harvest cost per acre for a stand-sequence-year combination.

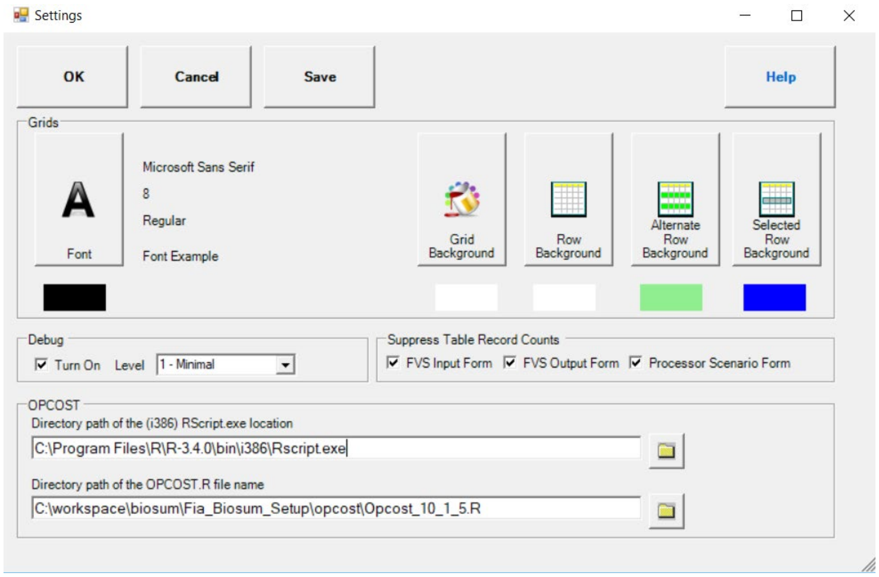
As of December 2018, OpCost encodes 24 models (equations), each of which uses some of the above information to predict the logging machine time required for a particular piece of machinery such as a mechanized harvester, tethered forwarder, stroke boom delimber or chainsaw that is used in one or more logging systems. OpCost and BioSum currently recognize and can model machine time requirements for 11 different harvest systems, each of which consist of multiple machines working in a coordinated fashion to move wood from standing tree to logs or chips on a truck. For some machines, multiple equations are included, and in these cases, an average of the predicted time required is used in calculating the machine cost. Many of the equations have limiting conditions that govern the range of input values for which valid predictions can be obtained. Some of these limits, such as a maximum average tree diameter or maximum slope or yarding distance, relate to the range of data from which the model was estimated; in other cases, the limit is necessary to avoid predicting, for example, a negative machine time. Owing to these limits, equations sometimes drop out of the running for some machines. For a few stands, all available equations may be ruled out for a given machine type—most commonly this happens with yarders on stands with extreme yarding distance (of over a mile). Because costs cannot be estimated for implementing management on these stands, these stands are dropped from a BioSum analysis. Any stands dropped for this reason will appear in the OpCost_errors table in the OpCost_input database at the end of a Processor operation. The OpCost_errors table may be useful for debugging, or for choosing a different harvest system to model for stands that end up in this table. These stands will not appear in the Opcost_output table or the harvest_cost table in the processor scenario and will not be processed further in a BioSum analysis unless rerun successfully with different inputs or a different harvest system. It is very important to check the OpCost_errors table to understand why some stands are dropped from the simulation and to satisfy yourself that this is an appropriate outcome, for example, because of excessive slope or yarding distance.

The equations included in OpCost are best thought of as a “starter set”. They may or may not be the best equations for a particular treatment in a particular place or forest type. For example, some were developed from small diameter conifer stands while others were developed for large diameter hardwoods. These equations are a vetted subset of those selected by the research collaborator at the University of Idaho responsible for the first version of OpCost (Bell et al. 2017), that replaced the Fuel Reduction Cost Simulator (FRCS, Fight et al. 2006) used in earlier versions of BioSum. As an Excel macro based tool, FRCS was challenging to document and modify as well as to integrate with the rest of BioSum. Some of the equations used in FRCS may not accurately reflect current technologies and harvest systems, and the OpCost effort was intended to pull in new equations and harvest systems, where possible. However, relatively few of the newer equations are based on studies conducted in the western U.S. Some users may wish to review the equations and the literature on which they are based. Thanks to OpCost’s modular design which relegates nearly all equations, units, limiting criteria and parameters to tables in an Access database, opcost_ref, the equations and parameters can be easily inspected, supplemented, adjusted and replaced as needed.

OpCost Settings

OpCost settings are accessible from the **<Settings>** menu at the top of any BioSum screen. The OpCost settings are at the bottom of the settings dialog and include controls for entering or confirming the full path (including directories) to both the binary file that implements the Rscript interpreter and to the OpCost R script (a plain text .R file).

1. Open the OPCOST settings dialog by clicking the **<Settings>** menu at the top of the BioSum window.



Microsoft Sans Serif
8
Regular
Font Example

Debug
☑ Turn On Level 1 - Minimal

Suppress Table Record Counts
☑ FVS Input Form ☑ FVS Output Form ☑ Processor Scenario Form

OPCOST
Directory path of the (i386) RScript.exe location
C:\Program Files\R\R-3.4.0\bin\i386\Rscript.exe

Directory path of the OPCOST.R file name
C:\workspace\biosum\Fia_Biosum_Setup\opcost\Opcost_10_1_5.R

Figure 5.5 – BioSum Settings dialog.

2. The first entry field will typically already be populated with the path to the Rscript executable file in the R folder on the C:\ drive, but it is worth checking to ensure that the location is correct. If using the 64-bit version of BioSum, the x64/Rscript.exe should be selected. Or when using the 32-bit version of BioSum, the i386/Rscript.exe should be selected. OpCost was written and tested in version 4.4.0 of R, and is not guaranteed to work in newer versions.
3. The second field should point to the OpCost R script. Select the folder icon next to **Directory path of the OPCOST.R file name** and navigate to the R script found here: C:\Program Files (x86)\FIA PNW Portland Forestry Sciences Lab\FIA Biosum *version*\OpCost. Select the OpCost_*version*.R file you wish to use, and click **<Open>**.
4. Click **<Save>** to save the settings specified in the dialogue. If **<OK>** is selected, the settings will be used during the current BioSum session and then saved when BioSum is closed.

Start BioSum Processor

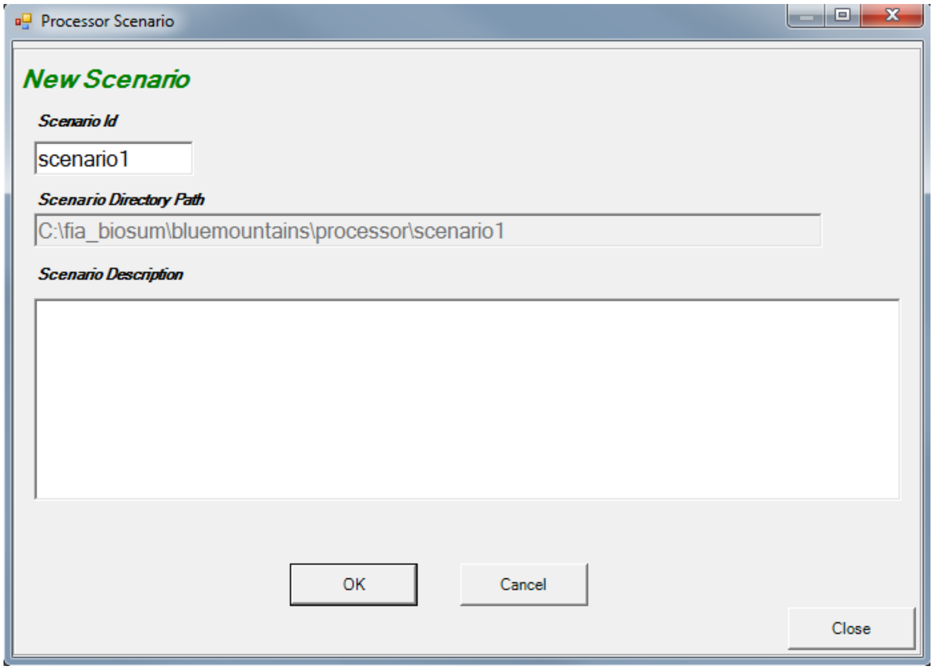
This task consists of several steps through which Processor scenarios are defined and executed to produce intermediate outputs that serve as inputs to the **Core Analysis** module. Calculations depend on links among tables in project_name/db/master.mdb, project_name/db/ref_master.mdb, project_name/fvs/data/ /BiosumCalc/variant_code_Package_ID_TREE_CUTLIST.mdb, and a number of scenario-specific tables within project_name/processor/db/scenario_processor_rule_definitions.mdb. Tables that are used as inputs include:

- The *plot* and *cond* tables in master contain information on the stands and conditions loaded in the current project.
- The *variant_tree_cutlist* tables contain biomass and volume estimates for harvested trees calculated using the FIADB Oracle Schema.
- The *tree_species* table is a reference table used to calculate the weight of harvested trees and convert FIA species codes to those used in FVS.
- The *tree_species_groups* and *diameter_groups* tables contain user-specified species and diameter group parameters.

Output from Processor, which serves as essential input to Treatment Optimizer, is stored at project_name/processor/Scenario_name/db/Scenario_results.mdb and includes:

- The *harvest_costs* table, which stores cost per acre information generated by OpCost, and
- The *tree_vol_val_by_species_diam_groups* table, which stores key volume and value information by species and diameter groups.

1. To start the BioSum Processor, click the **<Start BioSum Processor>** button.
2. The **Processor Scenario** window will open. The first time BioSum Processor is started, a default scenario will be created titled **scenario1.** If scenario1 has already been defined and you wish to create a new scenario, click **<New>.** Enter a scenario name and description, then **<OK>, to begin work with a new scenario, or <Cancel> to return to the processor scenario selection dialog**


Processor Scenario

New Scenario

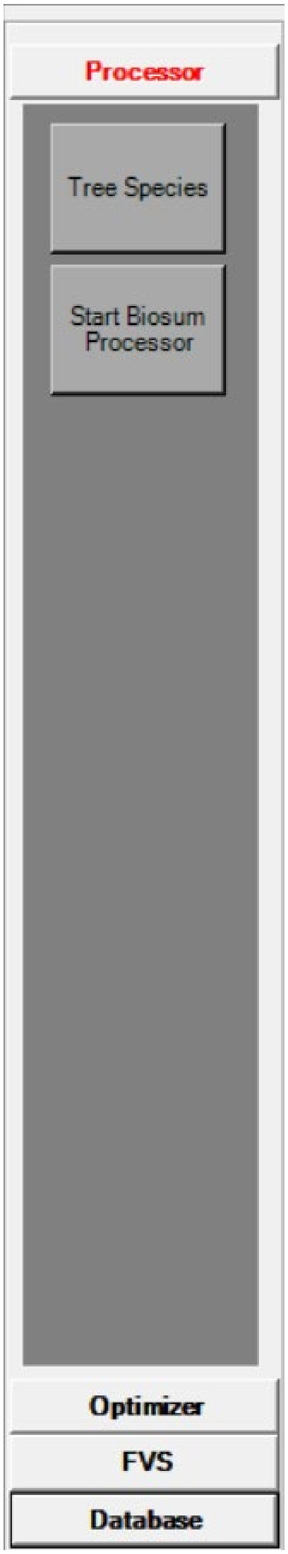
Scenario Id: scenario1

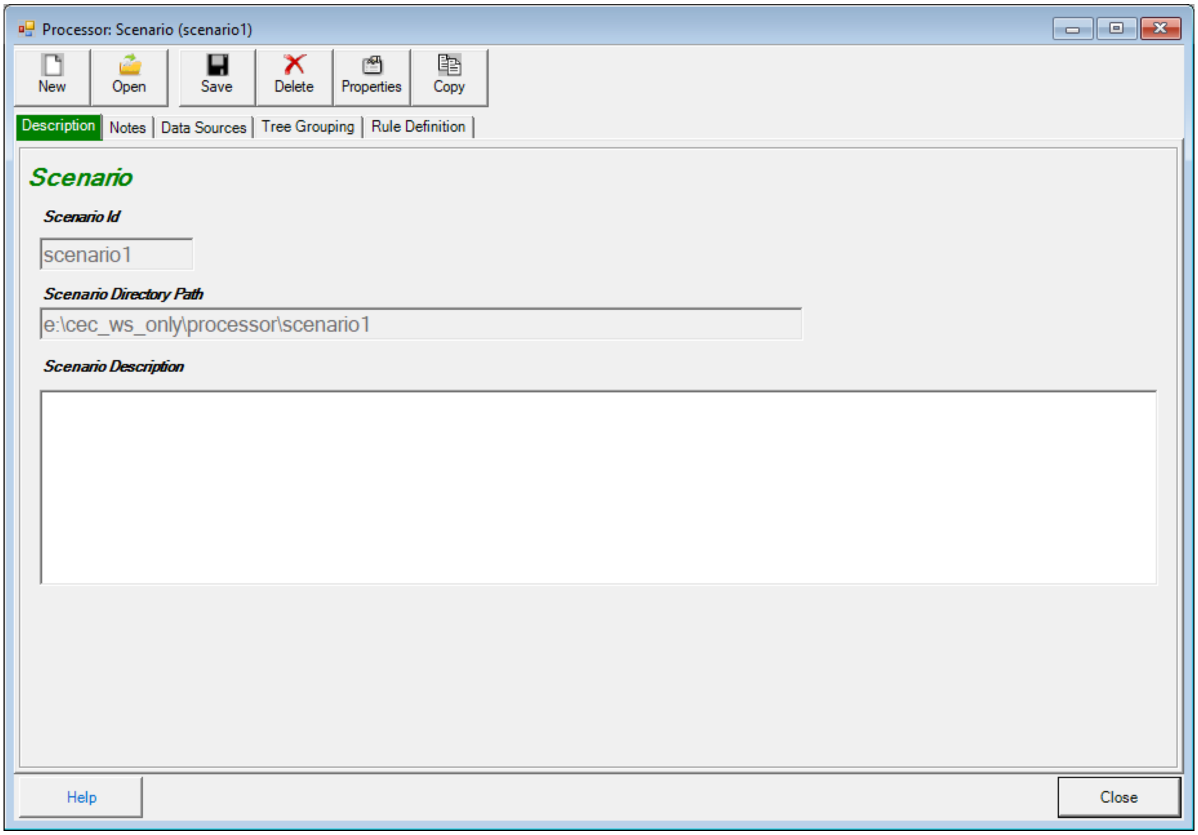
Scenario Directory Path: C:\fia_biosum\bluemountains\processor\scenario1

Scenario Description

Figure 5.6 – New processor scenario dialog.

3. If not initiating a new processor scenario, select the scenario that you wish to define or refine in the **Scenario List** and then click **<OK>.**





Scenario

Scenario Id

scenario1

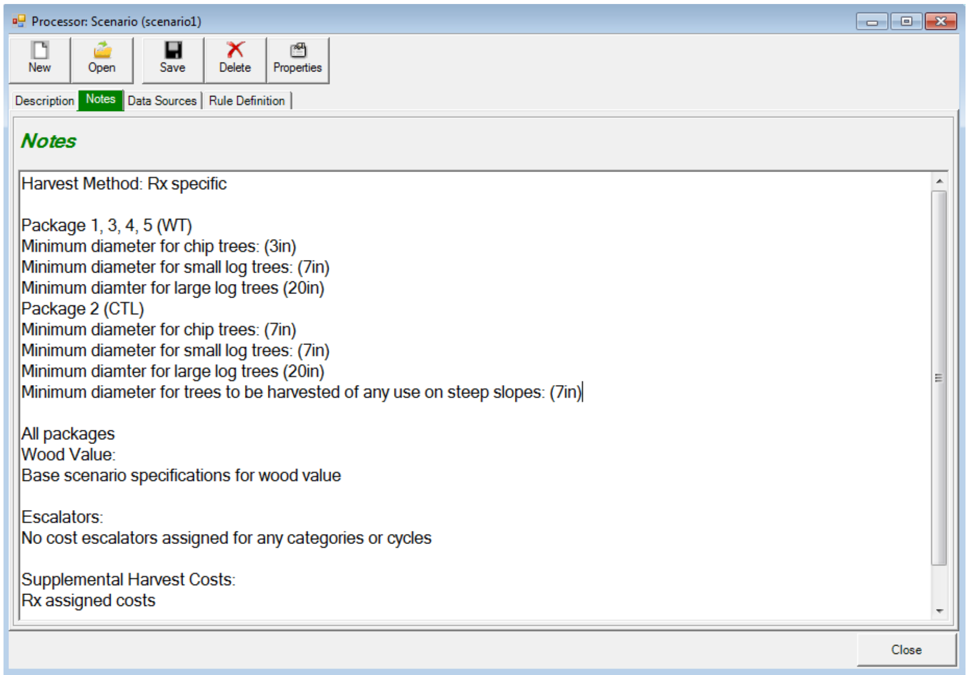
Scenario Directory Path

e:\cec_ws_only\processor\scenario1

Scenario Description

Figure 5.7- Processor scenario selection dialog.

4. The Processor Scenario window has five top-level tabs: Description, Notes, Data Sources, Tree Grouping, and Rule Definition and 6 action buttons (new, open, save, delete, properties and copy).
    a. The function of most of the action buttons is straightforward, but the copy function may be less intuitive. To copy an existing scenario, first create a New scenario. With the new scenario open, select copy, wait a while for choices to appear, then choose a scenario to copy into the currently open scenario. A dialog will appear asking for confirmation of the desire to copy FROM scenario A to scenario B—if the dialog looks right, choose Yes. A Done/OK dialog will display when copying is complete.
    b. The **Description** tab provides a **Scenario Description** text box to enter or revise brief descriptive information about the processor scenario.
    c. The **Notes** tab accesses a text box into which extensive notes may be recorded about the processor scenario for future reference.



Harvest Method: Rx specific

Package 1, 3, 4, 5 (WT)
Minimum diameter for chip trees: (3in)
Minimum diameter for small log trees: (7in)
Minimum diamter for large log trees (20in)
Package 2 (CTL)
Minimum diameter for chip trees: (7in)
Minimum diameter for small log trees: (7in)
Minimum diamter for large log trees (20in)
Minimum diameter for trees to be harvested of any use on steep slopes: (7in)

All packages
Wood Value:
Base scenario specifications for wood value

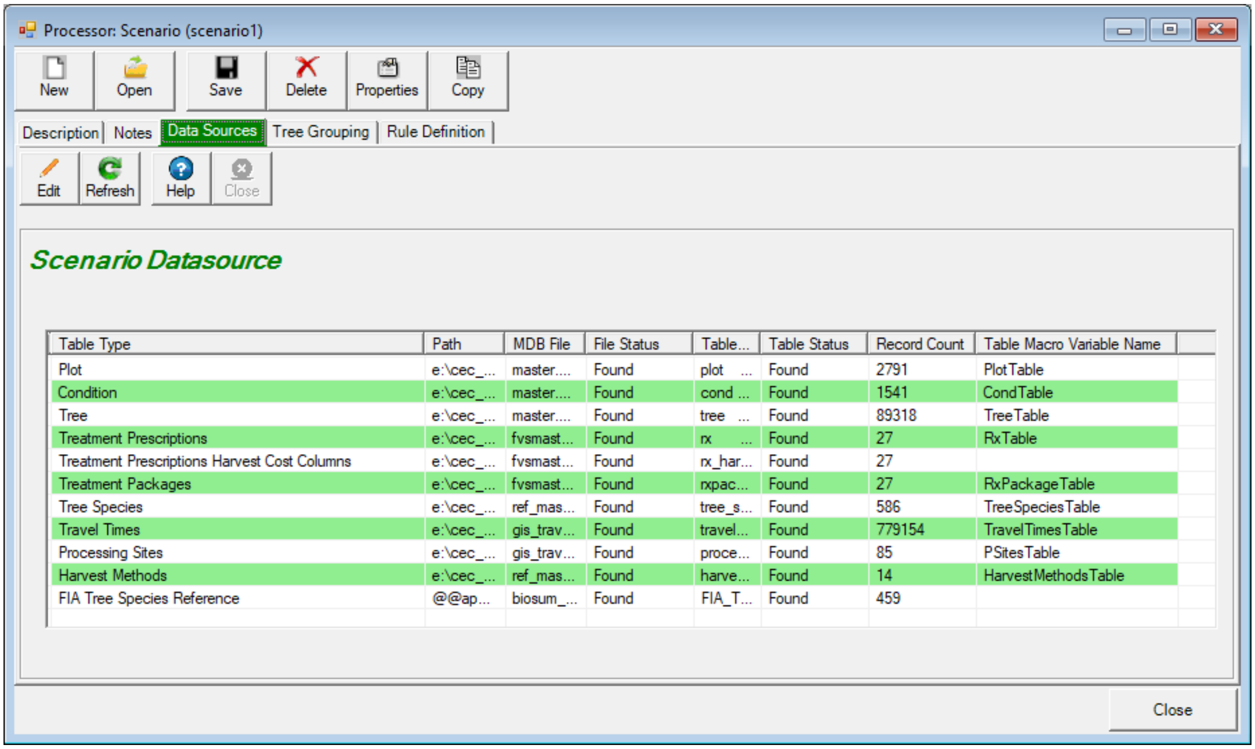
Escalators:
No cost escalators assigned for any categories or cycles

Supplemental Harvest Costs:
Rx assigned costs

Figure 5.8 – Notes tab of Scenario window.

d. The **Data Sources** tab displays pointers (file paths, file names, table names, status, records counts, etc.) to all types of source data used in the Processor scenario. Any of these data sources can be copied to another table or database and the pointer updated to point to the copy instead of the original data source. These copies can then be updated or customized to allow consideration of different situations. For example, if it was desired to customize the diameter groups for a particular processor scenario (and the core analysis scenarios that link to that processor scenario), it is easy to copy the tree_diam_groups table to another location (in the same database file or a different one) and edit the entries in the copy. To edit the pointer to the data source, and to make copies of data sources, select a table type and click **<Edit>.** The **Edit Data Source** window will appear. Here you can move, copy, or rename existing Access database files and tables, and reset links for any table type.

   Caution: Making changes to data sources is an advanced capability, not to be undertaken lightly or by BioSum beginners, and has the potential to be confusing or produce unintended consequences.



Scenario Datasource

Table Type	Path	MDB File	File Status	Table...	Table Status	Record Count	Table Macro Variable Name
Plot	e:\cec_...	master....	Found	plot ...	Found	2791	PlotTable
Condition	e:\cec_...	master....	Found	cond ...	Found	1541	CondTable
Tree	e:\cec_...	master....	Found	tree ...	Found	89318	TreeTable
Treatment Prescriptions	e:\cec_...	fvsmast...	Found	rx ...	Found	27	RxTable
Treatment Prescriptions Harvest Cost Columns	e:\cec_...	fvsmast...	Found	rx_har...	Found	27	
Treatment Packages	e:\cec_...	fvsmast...	Found	rxpac...	Found	27	RxPackageTable
Tree Species	e:\cec_...	ref_mas...	Found	tree_s...	Found	586	TreeSpeciesTable
Travel Times	e:\cec_...	gis_trav...	Found	travel...	Found	779154	TravelTimesTable
Processing Sites	e:\cec_...	gis_trav...	Found	proce...	Found	85	PSitesTable
Harvest Methods	e:\cec_...	ref_mas...	Found	harve...	Found	14	HarvestMethodsTable
FIA Tree Species Reference	@@ap...	biosum_...	Found	FIA_T...	Found	459	

Figure 5.9 – Data Sources tab of the Processor Scenario window.

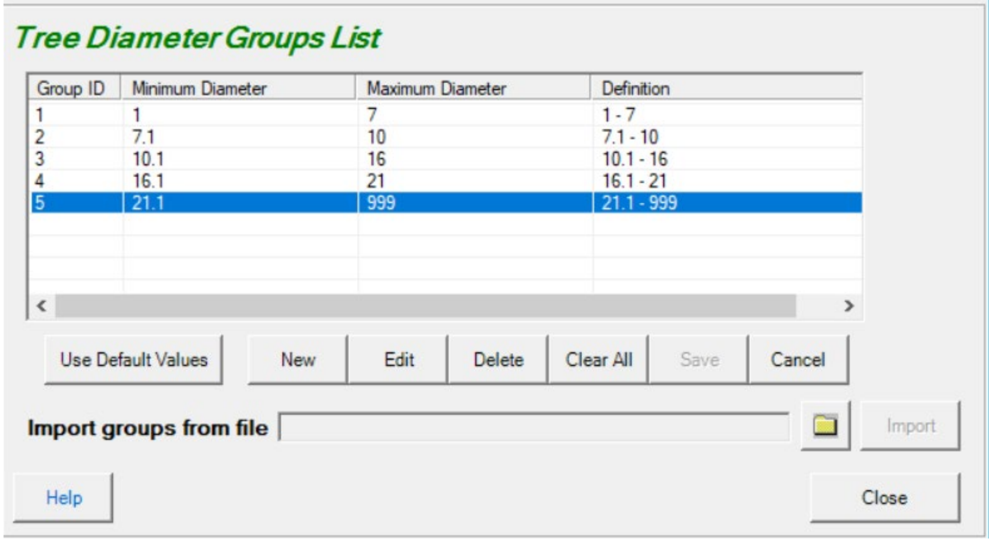
e. The **Tree Grouping** tab provides access to two grouping definitions, accessed by buttons: (1) Tree Diameter Groups and (2) Tree Species Groups—assign species groups. The data entered in these dialogs determines how BioSum summarizes volume, biomass and value by size class (diameter group) and species group. When parameterizing the Processor scenario via Rule definitions, further along in the Processor work flow, you'll have the opportunity to assign merchantable values for harvested trees for each combination of diameter and species group specified here as well as energy wood value per unit weight.

Note that altering these diameter or species group specifications later, after having run Processor (and this is NOT advised), generates a need to re-run the processor scenario and all treatment optimizer scenarios that depend on it; otherwise, the database will be corrupted in that entries in the tree_vol_val_by_species_diam_groups table, and in the treatment optimizer results that are linked to them, will be inconsistent with the most recently entered limits.

Tree Diameter Groups

The form accessed from this button is used to specify diameter groups by which harvested tree volume and value will be summarized. Alternatively, a button on the form allows loading of pre-specified diameter group specifications from a text file.

Click **<Tree Diameter Groups>** to open the Tree Diameter Groups List dialog.



Tree Diameter Groups List

Group ID	Minimum Diameter	Maximum Diameter	Definition
1	1	7	1 - 7
2	7.1	10	7.1 - 10
3	10.1	16	10.1 - 16
4	16.1	21	16.1 - 21
5	21.1	999	21.1 - 999

Import groups from file

Figure 5.10 - Tree Diameter Groups entry form.

To enter diameter groups via this form:

i. To add a new diameter group, click **<New>**. Enter minimum and maximum diameter values in the **Tree Diameter Groups** edit window. Values are entered and displayed in inches. An unlimited number of non-overlapping diameter groups can be specified; they must be specified in ascending order. The maximum diameter for the last diameter group entered should be at least as large as the largest tree that might be cut by any prescription in any stand; 999 is a good choice to ensure that all trees will be accounted for in volume, biomass and value summaries. **Important! It is incumbent on the analyst to define diameter groups that comport with brush-cut, chip, small and large tree diameter thresholds limits specified during the work flow defined by the Start BioSum Processor task**. For example, if trees less than 5" diameter are to be directed to the energy wood bin, there should be a break in the diameter group list at 5". Or, if in some packages, trees less than 6" are to be directed to energy wood bin, but in other packages the threshold is 5", diameter class limits should be defined to demarcate one or more groups <5", a group between 5 and 6" and one or more groups >6".

ii. To make changes to an existing diameter group definition, select the group from the list and click **<Edit>**.

iii. To load, or revert to, the default diameter group specification click <**Use Default Values**>; these are listed in Table 5.1.

Table 5.1 – Default diameter group values.

Group ID	Minimum Diameter	Maximum Diameter
1	1	7
2	7.1	10
3	10.1	16
4	16.1	21
5	21.1	999

iv. To delete a diameter group, select that group to highlight it and click **<Delete>**. To delete all diameter classes click **<Clear All>**.

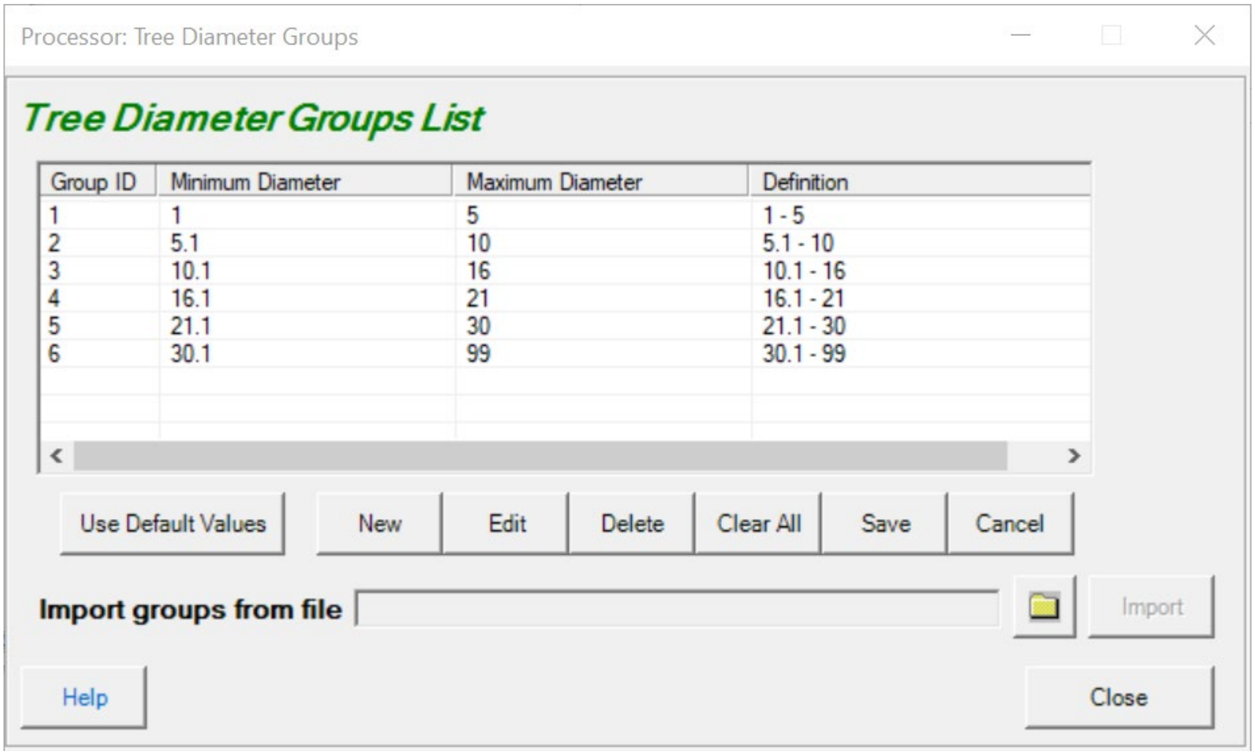
To import diameter class specifications from a text file:

When a large number of diameter classes are needed, specification via the **Tree Diameter Groups** editor may be cumbersome and efficiency may be gained by importing them from a text file. This workflow consists of 4 steps:

i. Using notepad (or a text editor of your choice) specify the maximum diameter for each of the tree species groups. The diameter values should be in ascending order with one value on each line. Biosum tree diameter groups are precise to the first decimal place. Values with more decimal places will be rounded to the closest tenth. For example, the contents of a diameter class specification text file suitable for import might be the following six lines:

```
5
10
16
21
30
99
```

which would generate six diameter classes:



Processor: Tree Diameter Groups

Tree Diameter Groups List

Group ID	Minimum Diameter	Maximum Diameter	Definition
1	1	5	1 - 5
2	5.1	10	5.1 - 10
3	10.1	16	10.1 - 16
4	16.1	21	16.1 - 21
5	21.1	30	21.1 - 30
6	30.1	99	30.1 - 99

Figure 5.11

ii. After you have created and saved the text file to your computer, click the folder button that appears above the close button near the bottom of the screen to specify the files location.

iii. When the **Import groups from file** text box contains the path to your selected file, the <**Import>** button will become enabled. Click this button to begin the import process. As the warning message indicates, the imported groups will overwrite the existing contents of the **Tree Diameter Groups List**.

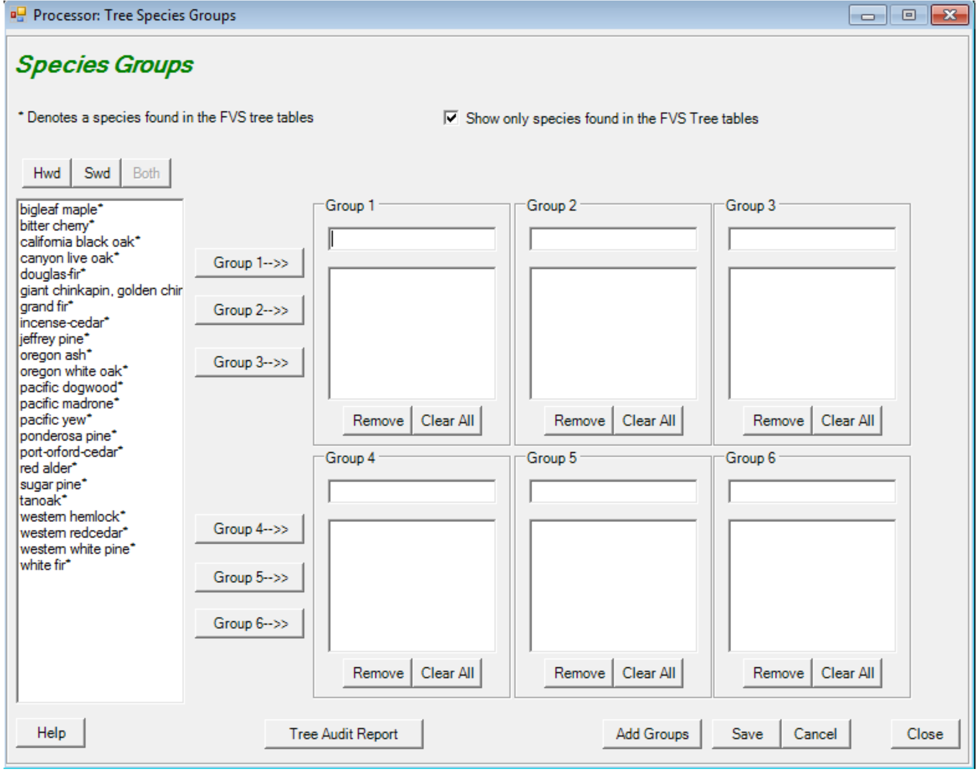
iv. Biosum will determine the Group ID, Minimum Diameter, and Definition values based on the contents of the text file. The default minimum diameter for Group ID 1 is 1. This can be changed after the import process by editing tree species group 1. The minimum diameter for the remaining groups is the maximum diameter for the preceding group + 0.1. BioSum does not allow gaps between tree diameter classes.

Whichever way diameter class information was specified (entering the form or importing from text file), if satisfied with the values in the Tree Diameter Groups List, click **<Save>** to save the values. Alternatively, click **<Cancel>** and close the **Tree Diameter Groups** window to revert to the previous diameter class specification (if any).

Tree Species Groups

BioSum summarizes volume, biomass and value by size class (diameter group) and species group. When parameterizing Processor towards the end of this module, merchantable values for harvested trees will need to be assigned for each combination of diameter and species group. Before that can happen, species groups must be assigned.

i. Click the **<Tree Species Groups>** button to display the **Species Groups** window.



* Denotes a species found in the FVS tree tables

☑ Show only species found in the FVS Tree tables

bigleaf maple*
bitter cherry*
california black oak*
canyon live oak*
douglas-fir*
giant chinkapin, golden chir
grand fir*
incense-cedar*
jeffrey pine*
oregon ash*
oregon white oak*
pacific dogwood*
pacific madrone*
pacific yew*
ponderosa pine*
port-orford-cedar*
red alder*
sugar pine*
tanoak*
western hemlock*
western redcedar*
western white pine*
white fir*

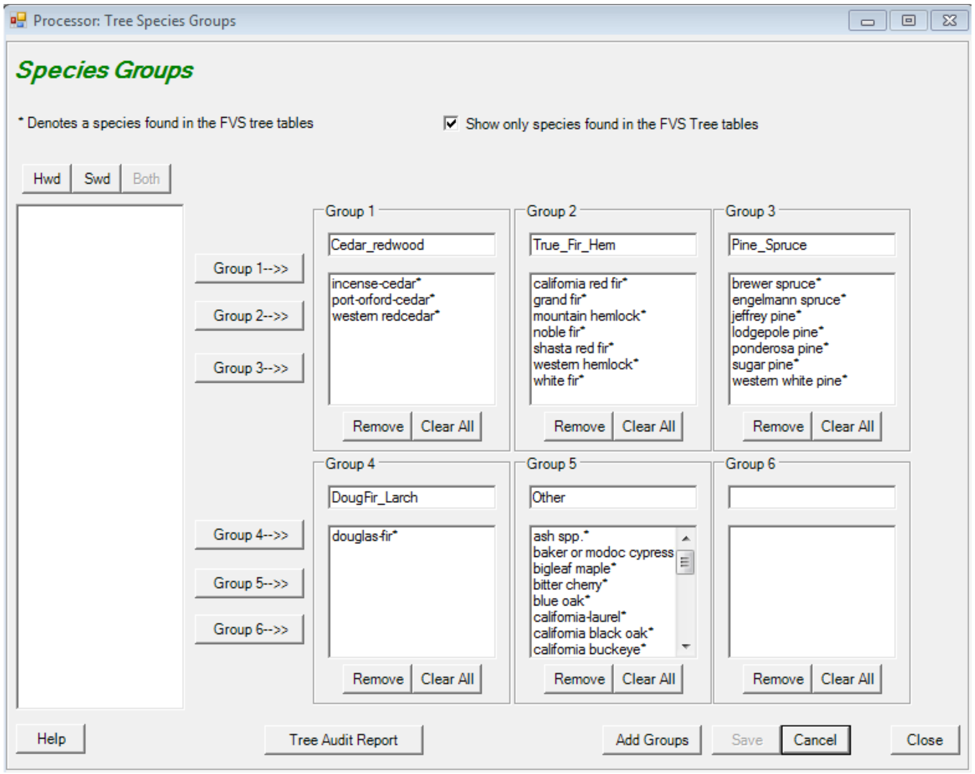
Figure 5.12 – Tree species groups window.

ii. Click the check box at the top of the window, next to **"Show only species found in the FVS Tree Tables"** to limit the display of tree species common names to only those present in the project dataset.

iii. Select a species from the list on the left and click any of the **<Group>** buttons to insert the species into that group. Note that species are removed from the list on the left as they are entered into groups. Enter a group name in the text box above each group species listing; blank names are not allowed. The **<Remove>** button will remove the selected species from the group and the **<Clear All>** button will remove all species from the group, returning them to the full list of unallocated species at the left edge of the species groups form. Additional groups can be added by clicking the **<Add Groups>** button at the bottom of the form.

iv. The **<Tree Audit Report>** button pulls up the Tree Species audit window, should the analyst need to edit tree species records or rerun an audit while using this form.

v. When finished assigning species to groups, the list of unallocated species will be empty. Click **<Save>** and then **<Close>** to complete this task.



Species Groups

* Denotes a species found in the FVS tree tables

☑ Show only species found in the FVS Tree tables

Group 1: Cedar_redwood
incense-cedar*
port-orford-cedar*
western redcedar*

Group 2: True_Fir_Hem
california red fir*
grand fir*
mountain hemlock*
noble fir*
shasta red fir*
western hemlock*
white fir*

Group 3: Pine_Spruce
brewer spruce*
engelmann spruce*
jeffrey pine*
lodgepole pine*
ponderosa pine*
sugar pine*
western white pine*

Group 4: DougFir_Larch
douglas-fir*

Group 5: Other
ash spp.*
baker or modoc cypress
bigleaf maple*
bitter cherry*
blue oak*
california-laurel*
california black oak*
california buckeye*

Group 6:

Figure 5.13 - All species have been grouped and group names have been added.

f. The **Rule Definitions** tab is a trigger that, after a moderate delay, the length of which depends on the size of the project and can be as long as a few minutes, displays six, second-tier tabs for entering processor scenario parameters and selecting which packages and stands to process: **Harvest Method**, **Move-In Cost**, **Wood Value**, **Escalators**, **Supplemental Harvest Costs**, and **Run**. Each of these second tier tabs access parameter settings that control some aspect of the Processor Scenario. If a scenario, say TimberPrice1 is copied into a new scenario name, say TimberPrice2, all of these parameter settings will be copied along with it. Then, if interested, for example, in the effect on treatment feasibility of higher or lower prices for merchantable and/or energy wood, it's easy to modify wood values stored in the TimberPrice2 scenario, re-run BioSum, and see how the effect plays out.

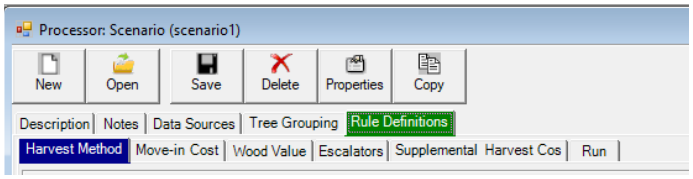


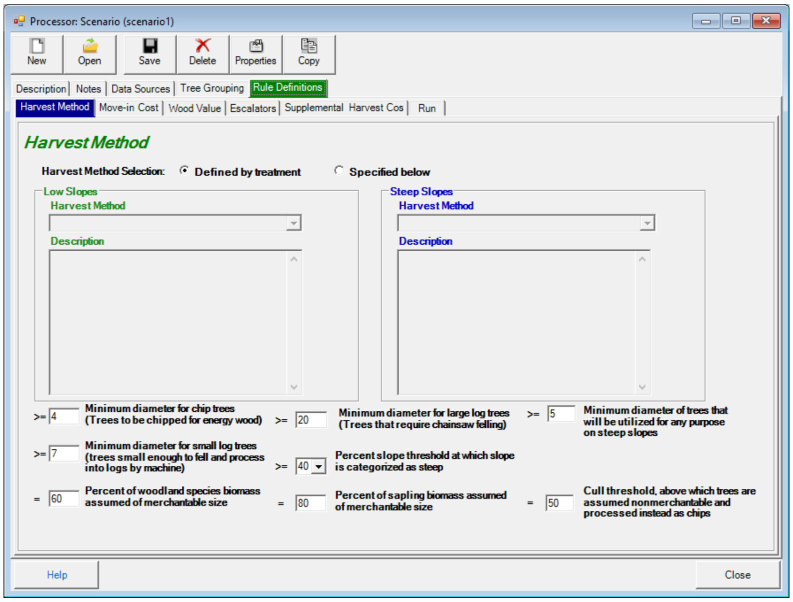
Figure 5.14 – Harvest Method is the first second-tier tab, nested beneath the Rule Definitions tab of the Processor Scenario window.

i. **Harvest Method:** Every stand-treatment combination must have an associated harvest method for OpCost to simulate costs when the information is passed to OpCost by BioSum Processor. Harvest methods can be assigned within the BioSum FVS module when prescriptions (Rx) are specified, or here, via the Harvest Method fields that, when populated, apply to all treatments in the scenario (Figure 5.19).

   1. By default, BioSum Processor will use the harvest methods that were defined for each treatment during treatment creation (FVS module). The <**Defined by treatment**> radio button will be toggled as selected.
   2. To instead define two standard harvest methods (one for steep, one for gentle slopes) that will be applied for all treatments in the processor session, select the radio button <**Specified below**>. Select **a Low Slope Harvest Method** and a **Steep Slope Harvest Method** for the scenario using the drop-down menus. A description of each method is provided in the **Description** text box. A current list and description of the harvest methods supported by BioSum and OpCost can also be found in **Appendix A** of this User Guide.
   3. If different than the displayed default values, three tree size parameters can be defined by revising the entries in their respective entry fields: 1) **Minimum diameter for chip trees**—trees smaller than this may be harvested as part of the prescription but will not be collected to the landing for utilization; 2) **Minimum diameter for small log trees**—these are trees that can be harvested and processed by machine (if harvested under a mechanized harvest system) and which have boles potentially suitable for utilization as merchantable logs (not chips); 3) **Minimum diameter for large log trees**—trees larger than this cannot be harvested and processed by mechanized equipment; rather they must be manually felled, bucked and yarded or skidded to the landing. VERY IMPORTANT: As of May 2023, the equations in OpCost that estimate mechanized harvesting cost will fail if the quadratic mean diameter of small log trees is 21 inches or greater. While trees larger than this threshold may, in fact, be harvested using a mechanized harvester, currently available equations are not capable of estimating the machine time required for harvesting such trees and they should be handled instead as large log trees (which are modeled in OpCost as manually felled). Stands with

a QMD for small log trees of 21 inches or larger will be dropped from analysis until new logging cost equations are developed and incorporated into OpCost. Note that "chip trees", as used here, refers to size class of trees from a harvest cost calculation point of view—these trees may be chipped and utilized as energy wood or not chipped and utilized as merchantable wood, or not utilized at all, depending on other settings selected by the user in the Processor module. Also, note that chipped wood (to be used for bioenergy, for example) may include either the boles or entirety of trees in the chip size class (depending on harvest system) and also the tops and limbs of merchantable sized trees (that may be costed as small or large log trees) and the entirety of small and large log trees of noncommercial species.

4. Define the **Percent slope threshold at which slope is categorized as steep.** Stands on slopes greater than or equal to this threshold will be modeled as harvested using a harvest method appropriate for steep slopes, whether that method is determined at prescription level or for the processor scenario.
5. The **Percent of woodland species biomass assumed of merchantable size** parameter determines how BioSum and OpCost account for harvesting costs for these species under different harvest methods. This assumption is needed because FIA does not have separate estimates of volume or biomass for merchantable and non-merchantable parts of these trees. Available equations estimate total volume and biomass.
6. The parameter **Percent of sapling biomass assumed of merchantable size** is needed because trees smaller than 5 inches dbh have no calculated bole volume, only total volume, in FIA databases. Whether all or parts of these small trees are utilized as merchantable logs, energy wood or not at all, the percent of their volume in boles is needed to accurately estimate treatment costs, and this parameter provides the basis for this.
7. The **Minimum Diameter of Trees to be harvested for All Uses ON STEEP SLOPES,** tells OpCost which trees need to be accounted as being transported to the landing, versus cut and left.
8. The **Cull threshold, above which trees are assumed nonmerchantable and processed instead as chips**, enables customization of how much of a tree must be rated as cull before BioSum assumes that it has no merchantable value and reverts to utilization as energy wood.



Harvest Method

Harvest Method Selection: ● Defined by treatment ○ Specified below

Low Slopes
Harvest Method
Description

Steep Slopes
Harvest Method
Description

>= 4 Minimum diameter for chip trees (Trees to be chipped for energy wood)

>= 20 Minimum diameter for large log trees (Trees that require chainsaw felling)

>= 5 Minimum diameter of trees that will be utilized for any purpose on steep slopes

>= 7 Minimum diameter for small log trees (trees small enough to fell and process into logs by machine)

>= 40 Percent slope threshold at which slope is categorized as steep

= 60 Percent of woodland species biomass assumed of merchantable size

= 80 Percent of sapling biomass assumed of merchantable size

= 50 Cull threshold, above which trees are assumed nonmerchantable and processed instead as chips

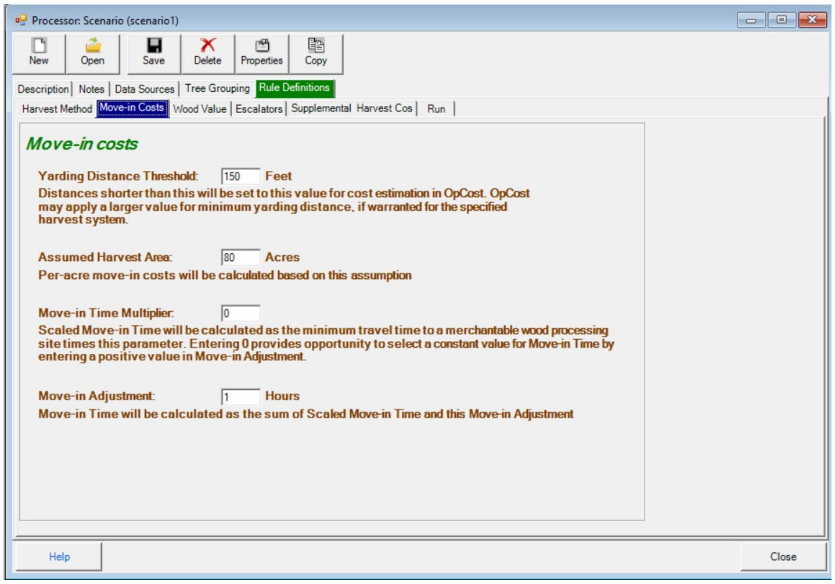
Figure 5.15 – The harvest method tab parameters will need to be specified by the user when choosing to override the prescription specific harvest system choices with a single pair of systems for all treatments (one for low and one for steep slopes).

ii. **Move-in Costs:** This form contains three parameters that can be used to account for the costs of moving logging equipment to a forest operation and one, **yarding distance threshold**, that does not relate to move-in costs, but does not readily fit within any other dialog. To estimate move-in costs, OpCost must be supplied with a rough average of the time required to move forest operations equipment (e.g., feller-bunchers, forwarders, chippers) from a previous location (either a home-base or another forest operation) to the location of the FIA plot where the stand exists. It must also know the number of pieces of equipment that will need to be moved in—a statistic that OpCost derives from the harvest system chosen for implementation—and, to obtain per acre move-in costs, the area of a forest operation over which the move-in costs can be distributed.

1. The yarding distance threshold overrides the yarding distance calculated between the FIA plot and the nearest point on the road network to address issues that arise when short yarding distances are passed to the operations cost equations within OpCost. For example, if the calculated distance for a particular stand, based on FIA plot location and road position, is 3 feet, a threshold value of 100 feet will modify that 3 to 100 when that stand's data is passed to OpCost. For some of the equations

used in OpCost to estimate yarding or forwarding costs for some harvest systems, providing small values for average yarding distance produces anomalous results because the values are outside the range of data that were used to fit the equations. Setting the threshold to 150 feet or greater will likely avoid these anomalies, though for some harvest systems (e.g., helicopter-based ones), Processor and/or OpCost may internally override even this threshold with a higher threshold value.

2. Assumed Harvest Area, in acres, is used to convert move-in costs for the stand to a per acre cost that can be summed with the operations and supplemental harvest costs per acre to obtain total per acre costs. The parameter value should reflect the typical size of forest operations that implement the kinds of treatments being modeled.
3. Given the uncertainty concerning exactly where equipment might be based, one option for obtaining a rough approximation of move-in time (which OpCost uses to obtain move-in cost) is the simplistic assumption that equipment "lives" where merchantable wood processing facilities exist (i.e., in at least a semi-developed area), and specifically, at the nearest facility for processing merchantable wood. To model that assumption, the analyst would enter a "1" for the **Move-in Time Multiplier**. Alternatively, any non-negative value other than 1 can be selected to represent at time that is a fraction or multiple of the time to the closest wood processing facility. If desiring a move-in cost estimate that depends <u>only</u> on travel time to the nearest wood processing facility, ensure that the **Move-In Adjustment** is set to zero.
4. Another option is to assume a fixed move-in time for all stands that is independent of where stands are relative to wood processing facilities. To do so, set **Move-in Time Multiplier** to zero (effectively cancelling out the use of travel time in the calculation) and set the fixed **Move-in Adjustment** time (in decimal hours) to a non-negative value.
5. The third option is to combine approaches—e.g., a value of 0.5 for **Move-in Multiplier** and 0.75 for **Move-in Adjustment** would calculate move-in time as the sum of half the travel time to the nearest merchantable wood processing facility and 45 minutes.



Move-in costs

Yarding Distance Threshold: 150 Feet
Distances shorter than this will be set to this value for cost estimation in OpCost. OpCost may apply a larger value for minimum yarding distance, if warranted for the specified harvest system.

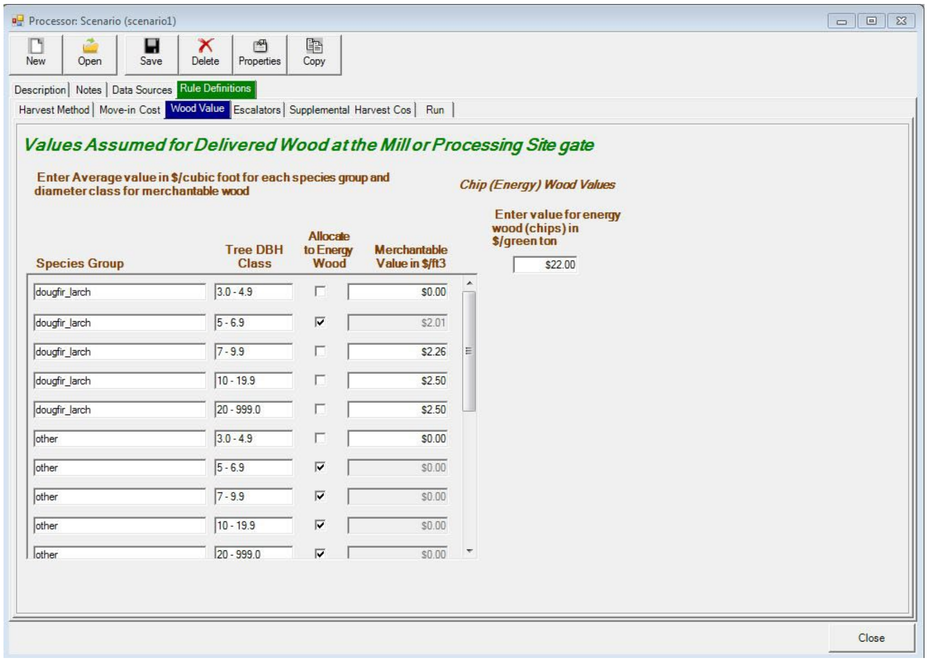
Assumed Harvest Area: 80 Acres
Per-acre move-in costs will be calculated based on this assumption

Move-in Time Multiplier: 0
Scaled Move-in Time will be calculated as the minimum travel time to a merchantable wood processing site times this parameter. Entering 0 provides opportunity to select a constant value for Move-in Time by entering a positive value in Move-in Adjustment.

Move-in Adjustment: 1 Hours
Move-in Time will be calculated as the sum of Scaled Move-in Time and this Move-in Adjustment

Figure 5.16: The Move-in Costs form contains three parameters that can be used to account for the costs of moving logging equipment to a forest operation and one that does not.

iii. **Wood Value:** This form provides for entering/revising the merchantable value in dollars per cubic foot, at the mill gate, for each combination of species and diameter group represented in the Processor scenario, and a value in dollars per green ton, at the delivery point (e.g., a biomass-based energy generating facility), for chipped residues (the material chipped at a treatment site and loaded onto a chip truck). The latter should be entered in the field labeled “Energy value for energy wood (chips) in $/green ton”. To allocate a species/diameter group combination to energy wood, use the **Allocate to Energy Wood** checkbox. Note: if silvicultural sequences are designed to have different thresholds, or wood allocation choices, it is possible to select parameters, and run processor for one set of sequences with one set of wood value parameters, then run another set of sequences with a modified set of parameters.



Values Assumed for Delivered Wood at the Mill or Processing Site gate

Enter Average value in $/cubic foot for each species group and diameter class for merchantable wood

Species Group	Tree DBH Class	Allocate to Energy Wood	Merchantable Value in $/ft3
dougfir_larch	3.0 - 4.9	☐	$0.00
dougfir_larch	5 - 6.9	☑	$2.01
dougfir_larch	7 - 9.9	☐	$2.26
dougfir_larch	10 - 19.9	☐	$2.50
dougfir_larch	20 - 999.0	☐	$2.50
other	3.0 - 4.9	☐	$0.00
other	5 - 6.9	☑	$0.00
other	7 - 9.9	☑	$0.00
other	10 - 19.9	☑	$0.00
other	20 - 999.0	☑	$0.00

Chip (Energy) Wood Values

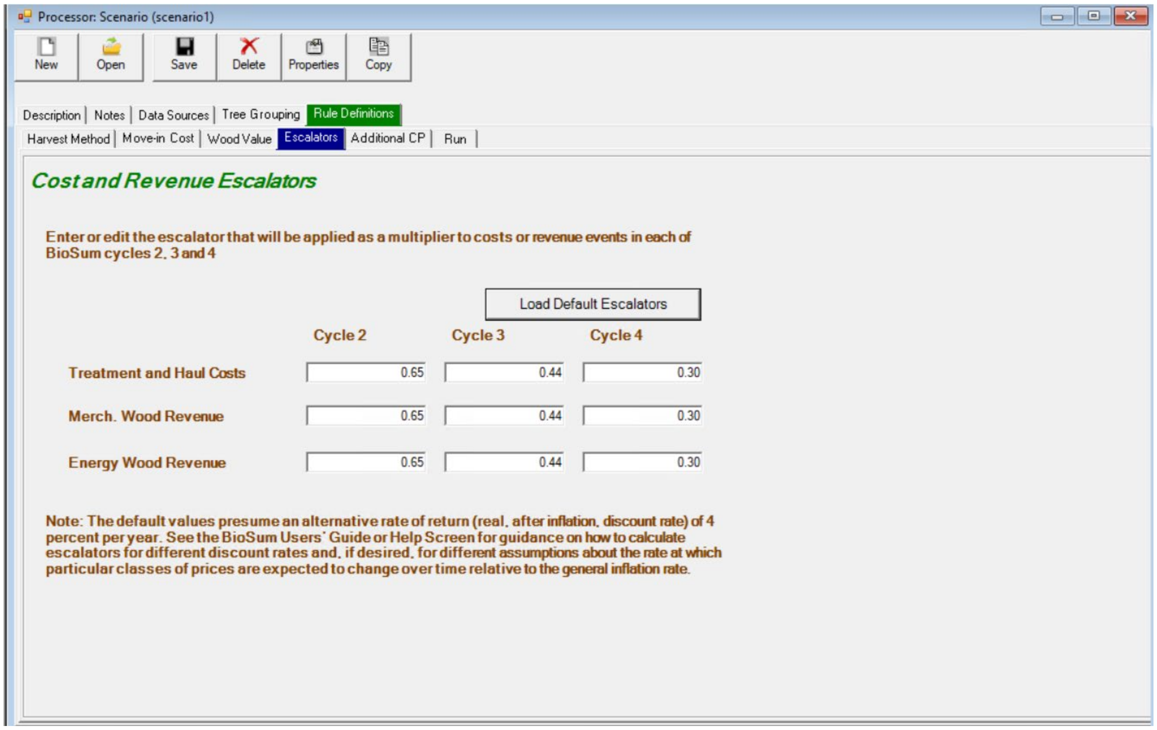
Enter value for energy wood (chips) in $/green ton: $22.00

Figure 5.17 – Wood Value tab, specify values assumed for delivered wood by diameter class and species group.

iv. **Escalators:** The escalators tab accesses a dialog for specifying multipliers that can be applied to costs incurred and revenues received at BioSum cycles 2, 3 and 4 to account for 1) a discount rate (alternative rate of return) and/or 2) anticipated differential appreciation in prices or costs among merchantable wood, bioenergy feedstocks (chips) and factor costs associated with implementing silvicultural prescriptions and hauling harvested wood. Either or both of these simulation elements can be accounted for, but if it is to be both, then the multipliers supplied by the analyst need to account for both elements. If not intending to account for either of these elements (rarely an appropriate choice, given that some positive discount rate almost always applies), all multipliers would be set to one, as they are in a new project or processor scenario. Note that there is no reason to specify a multiplier for BioSum cycle 1 because, given that it is assumed that costs and revenues occur at the beginning of cycle 1 (i.e., year 1, or close to it), any discounting or inflation between the vantage of the time point when the simulation is conducted and the realization of those costs and revenues isn’t significant.

Escalators that encode a default annual discount rate of 4 percent for cycles 2-4 and assume no differential in the inflation rates for prices of wood and bioenergy and treatment and haul costs can be summoned with the “Load Default Escalators” button to replace any currently specified escalators. These will reflect the nominal cycle length (of 5 or

10 years) selected during the Rx Packages definitions. Only one cycle length should be selected for a given BioSum project when specifying Rx Packages. If more than one cycle length was specified, default escalators will be assigned based on the longer of the cycle lengths defined (i.e., 10 years).



Cost and Revenue Escalators

Enter or edit the escalator that will be applied as a multiplier to costs or revenue events in each of BioSum cycles 2, 3 and 4

	Cycle 2	Cycle 3	Cycle 4
Treatment and Haul Costs	0.65	0.44	0.30
Merch. Wood Revenue	0.65	0.44	0.30
Energy Wood Revenue	0.65	0.44	0.30

Note: The default values presume an alternative rate of return (real, after inflation, discount rate) of 4 percent per year. See the BioSum Users' Guide or Help Screen for guidance on how to calculate escalators for different discount rates and, if desired, for different assumptions about the rate at which particular classes of prices are expected to change over time relative to the general inflation rate.

Figure 5.18 – Cost and revenue escalators tab showing default escalators representing a 4 percent discount rate.

Case 1: Discount rate—this is the most typical use of price and cost escalators in a BioSum analysis. The intent of this use case is to account for the alternative rate of return on capital that should be assumed in an investment analysis. This is especially relevant to an analysis of management on private lands, though it may also be relevant on public lands. The discount rate accounts for the delivery of, say, $1000 per acre in net revenue eleven years from now, at the beginning of the 2nd BioSum cycle (i.e., 2034), being worth less to a forest owner than receiving that same revenue today (in 2023). The present value (PV), that is to say, the value today, of $1000 received in 2034 is given by applying to the future value (FV) the formula:

$$PV = FV(1/(1+i)^{t})$$

where *t* is the number of years separating today and the future value (11 years in this case) and *i* is the interest rate, a.k.a. alternative rate of return. For this example, if an alternative rate of return of 4% is considered to be the best, deflated (that is to say, adjusted for inflation) return available today for capital invested in an asset with equivalent risk to that observed in forestry, PV is $1000(1/(1.04)^{11}) = 1000 * 0.650 =$ $650. The present value of $1000 received at the beginning of the 4th BioSum cycle (say 31 years from now) would be $300.

Discount rates affect how streams of costs and revenues associated with multiple, potentially desirable silvicultural sequences that could be applied in a stand are evaluated. When a silvicultural sequence must exceed a feasibility threshold (for example, present net revenue > 0) to be considered potentially optimal and/or when an economic criterion determines which sequence is best or is used to break ties, then these evaluations can be critical. With a 4 percent discount rate, a sequence that imposed costs of $400 per acre at year 1 (say for precommercial thinning) and returned $1000 per are in net revenue (sales of wood minus harvest and haul costs) in year 31 would have a negative present net revenue because the $1000 discounted to the present would be only $300 per acre of revenue, which is less than the $400 per acre expended on precommercial thinning at year 1. It might still be a desirable and viable option if the economic threshold specified in a scenario called for losing less than or equal to $100 per acre.

Of course, if the inflation rate (represented by *r*) is not zero, then net revenue in today's dollars would be greater at year 31 in nominal currency for that year. Take the example of a prospective (at year 31) $5000 per acre in sales of merchantable and energy wood and harvest and haul costs that sum to $4000, netting to +1000 using today's prices and costs. If the expected rate of inflation is 8 percent, as it was in 2022, the net revenue at year 31 in nominal 2054 dollars would be 1000*(1+r)t = $1000(1.08^{31})$= $10,868. However, future nominal dollars are of no great interest because financial analysis requires that all costs and revenues be "moved" to the same point in time for comparison, and typically, the present time is selected for this comparison point. Thus, that future net revenue of $10,868 in nominal 2054 currency would need to be discounted by dividing by (1.08^{31}), bringing us right back to $1000 in today's dollars. This is why in most circumstances, it is not necessary to account for the inflation rate *r* at all (but it is necessary to account for the discount rate, *i*).

The values to enter in the escalators registers on this screen should be calculated as $(1/(1+i)^t)$ for each value of t (e.g., 11, 21 and 31, if those are the first years of BioSum cycles 2, 3 and 4). In our example of a 4 percent real discount rate (net of inflation), these would compute as 0.6496, 0.4388 and 0.2965 for years 11, 21 and 31 (Cycles 2-4). For each column (BioSum cycle), enter the one multiplier associated with that cycle for every row—Operating costs, Merch and Energy wood revenue so that all costs and revenues are consistently discounted. The values will differ among rows only for scenarios in which inflation is assumed to behave differently among these three cost and revenue components (see next section).

Case 2: Differential appreciation—This use of the escalator fields is designed to enable simulation of scenarios in which users anticipate differentials in price and cost appreciation for some prices and costs relative to others. For example, consider this scenario: the crushing urgency of combatting climate change leads to dramatic and sustained subsidies, tax breaks and other policies that promote using wood as a construction material in lieu of concrete and steel because it avoids fossil C emissions and sequesters carbon for a very long time. It is easy to see how such demand-stimulating policies could result in the value of merchantable wood rising faster than inflation (and faster than both bioenergy prices and harvest and haul costs). Suppose a general inflation rate (applicable to energy wood revenue and costs of production) of 8 percent and a merchantable wood price inflation rate of 10 percent. In the simple, though unrealistic, case of needing to account for this differential but not needing to account for an alternative rate of return (i.e., a discount rate set at zero), we use the differential between the wood price inflation and general inflation, 2 percent, as the basis of computing the escalator for wood products prices. Because wood products prices are expected to enjoy a premium over and above general inflation, we would set multipliers as $(1+r)^t$, which in this case would be $(1.02)^{11} = 1.243$ for cost and revenue amounts associated with cycle 2, $(1.02)^{21} = 1.516$ for cycle 3 and $(1.02)^{31} = 1.848$ for cycle 4, if we assume that this differential persists over the entire simulation. If, instead, we believe that this differential will be a temporary ten-year "bump" that doesn't begin until ten years from now, then we would set the escalator to 1 for cycle 2, and 1.243 for cycles 3 and 4. Note that though wood product price appreciation reverts to the general inflation rate for the 4th cycle, it was elevated for 10 years and thus stays ahead of general inflation going forward – hence the continuation of the 1.243 escalator in cycle 4. All other escalators (for bioenergy and costs) remain set at 1 for all cycles because they track general inflation. Note that we don't use 8 and 10 to calculate escalators for all prices and costs because the 8 percent general inflation is already accounted—if we set the escalator for wood prices based on 10 percent, we would then have to discount by 8 percent inflation to bring it back to present value terms—which is the same as the net 2 percent used in this example. If we believe that policies of promotion will also lead bioenergy prices to rise faster than inflation, but somewhat less so than for wood (say 9 percent), we could calculate bioenergy escalators as a net 1 percent/year escalator (1.01^t).

Case 3: Discount rate *and* differential appreciation—As indicated earlier, escalators would almost never be based on differential rates alone because discount rates are an incontrovertible reality of valuation decisions. Economic theory and empirical evidence have confirmed that a dollar in the future is almost never worth as much as a dollar today, whether as a cost or a revenue, and whether it is a public agency or a private entity making those judgements. Different entities may have different rates of return, perhaps owing to different assumptions or risk profiles, but accounting for such differences is beyond the scope of what BioSum supports within the model and would have to be implemented exogenously if desired.

Within BioSum, the discount rate and differential appreciation can be accounted for simultaneously by the escalator settings. Consider this scenario: Discount rate of $i = 4$ percent, and an expectation that wood and bioenergy prices will track general inflation rates but treatment and haul costs will rise 1 percent faster than general inflation owing to their dependence on fossil fuel inputs, for the duration of the simulation ($r = 1$ percent). Both scenario aspects can be represented in the escalators by combining the interest rates, as appropriate for each economic element. For wood and bioenergy prices, the escalators (multipliers) would be calculated, if $i > r$ (discount rate greater than positive differential above inflation for the relevant cost or price), as $(1/(1+(i\text{-}r))^t)$, where t takes on the year in the cycle at which costs or prices occurs. In the very unlikely event that $r > i$, the multiplier would be calculated as $(1+(r\text{-}i))^t$ and the general case (that works regardless of relative magnitude of i and r) is $(1+(r))^t\ /(1+i)^t$

Escalator calculation tool—An Excel workbook is available at http://biosum.info/downloads/processor/Escalators.xlsx in which to enter assumptions about discount rate and, if warranted, differential appreciation rates per price and cost category, per cycle. The values calculated on that sheet can be transcribed into the Cost and Revenue Escalators dialog. A button on this dialog allows you to choose the default settings (4 percent discount rate, and no differential appreciation rates), which will then be applied, based also on the current cycle length specified in the prescription definition section of BioSum's FVS module.

v. **Additional CPA:** Recall that within the FVS module, additional cost per acre *flags* (not the actual costs) can be specified when prescriptions (Rxs) are defined. When coding the FVS simulation of packages containing prescriptions with additional CPAs, these flags were to have been set to be populated with 1's and 0's each cycle depending on whether the cost of the additional activity is to be incurred. ***This*** tab provides an interface for actually populating the BioSum cost variables associated with these cost components with analyst-assigned values.

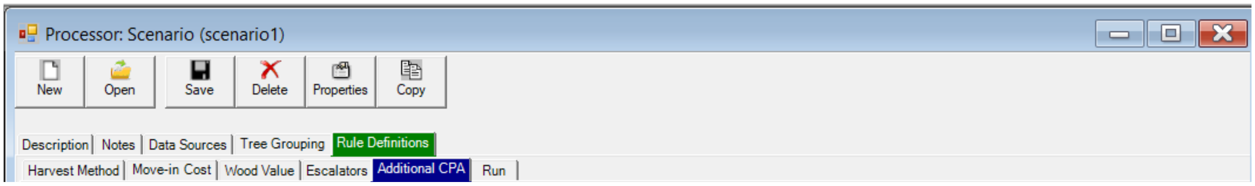
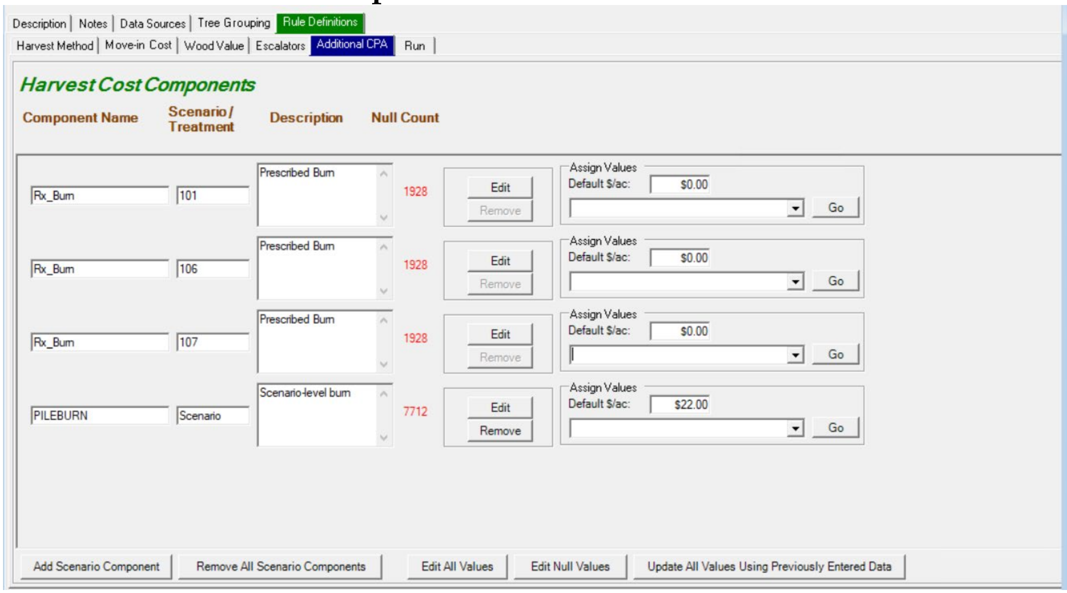


Figure 5.19 –Additional CPA tab—assign costs to previously defined cost components specific to each treatment and/or define and populate scenario harvest cost components that apply to all packages modeled in the processor scenario.

1. To assign a value to an Rx Harvest Cost Component that was created at the time the Rx was defined, find that component in the **Component Name** column (you may need to scroll if there are several). Optionally, the description for that Cost Component can be modified in the **Description** text box. The cost per acre MUST be defined in the **Assign Values: Default cost/ac** section to assess a cost. For Rx Harvest Cost Components, this is the final required step.

2. To add a new cost component to be applied to ALL treatments in this processor scenario, click **<Add Scenario Component>.** When the Harvest Cost window appears, select a cost component from the drop-down list, or enter a new cost component, then click **<OK>.** Scenario components can be

edited or removed by clicking the **<Edit>** or **<Remove>** buttons found next to the **Component Name** section.


Description | Notes | Data Sources | Tree Grouping | Rule Definitions
Harvest Method | Move-in Cost | Wood Value | Escalators | Additional CPA | Run
Edit
Remove
Go
Add Scenario Component
Remove All Scenario Components
Edit All Values
Edit Null Values
Update All Values Using Previously Entered Data

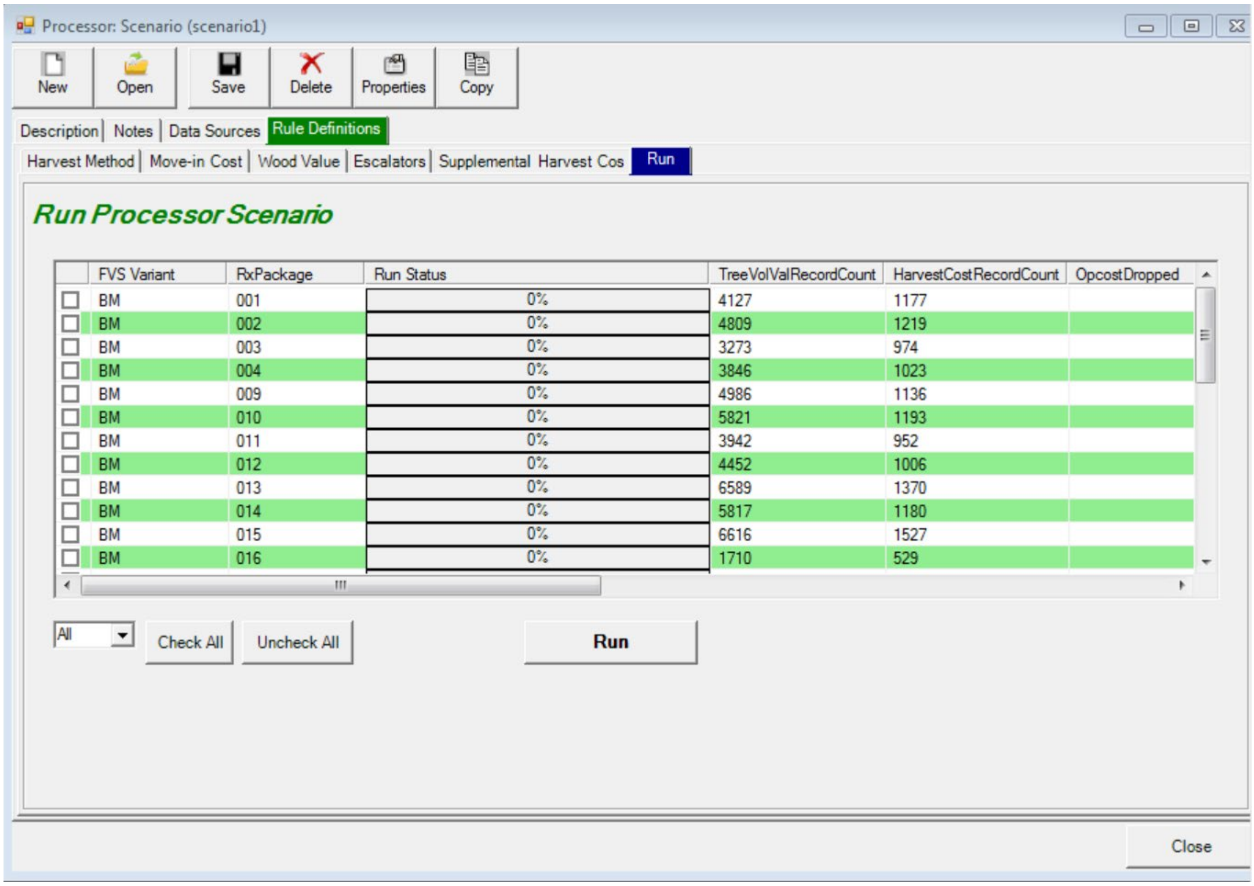
Harvest Cost Components

Component Name	Scenario / Treatment	Description	Null Count	Assign Values Default $/ac:
Rx_Burn	101	Prescribed Burn	1928	$0.00
Rx_Burn	106	Prescribed Burn	1928	$0.00
Rx_Burn	107	Prescribed Burn	1928	$0.00
PILEBURN	Scenario	Scenario-level burn	7712	$22.00

Figure 5.20 –Harvest Cost Components— Define and populate Scenario harvest cost components that should be applied to all packages harvested and modeled in the processor scenario.

3. Define the default dollar amount of the scenario component in the **Assign Values: Default cost/ac** section to assess a cost.
4. Use the pick list next to the <**Go>** button to select an option for assigning scenario component costs at the stand level. The CPA can also be reviewed/edited by using MS Access to examine the scenario_additional_harvest_costs table. This table can be found in the \processor\db\scenario_processor_rule_definitions.mdb and contains a column for each harvest cost component.

vi. Run: Once all the scenario rule definitions are complete, a processor simulation can begin. Note: Individual RxPackages within a single project may contain different Processor parameters by running a subset of rxpackages. For example, it may be the case that there are different minimum diameter thresholds in the rxpackages that use a Whole Tree harvest system, versus those using a Cut to Length method. In this case, users can input the Whole Tree parameters, run those packages through Processor, change the inputs to reflect a Cut to Length system, and then run the remaining packages.



Run Processor Scenario

	FVS Variant	RxPackage	Run Status	TreeVolValRecordCount	HarvestCostRecordCount	OpcostDropped
□	BM	001	0%	4127	1177	
□	BM	002	0%	4809	1219	
□	BM	003	0%	3273	974	
□	BM	004	0%	3846	1023	
□	BM	009	0%	4986	1136	
□	BM	010	0%	5821	1193	
□	BM	011	0%	3942	952	
□	BM	012	0%	4452	1006	
□	BM	013	0%	6589	1370	
□	BM	014	0%	5817	1180	
□	BM	015	0%	6616	1527	
□	BM	016	0%	1710	529	

Figure 5.21 – The Run tab dialog allows selection of the variant/Rxpackage combinations to be processed and provides a "Run" button to initiate processing.

1. Check the box next to any variant/rxpackage combinations to be included in the processor simulation. Silvicultural sequences (RxPackages) that do not involve mechanical thinning, for example a grow-only sequence, will not appear on the list, and cannot be run through Processor because there are no harvesting costs or wood volume or biomass to calculate. Stands can be processed one at a time, by package, by variant, or all stands in one run.

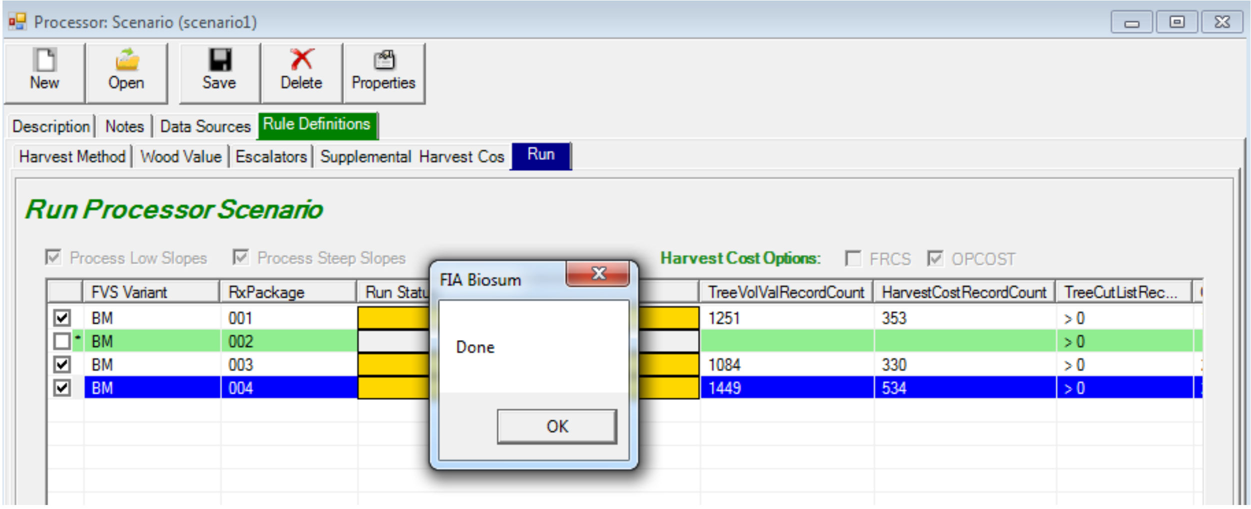
2. Click **<Run>** to start Processor. Depending on computer speed and data size, this can take from several minutes to over an hour.
3. When complete, a "Done" OK dialog will display (it may display underneath other windows on the desktop). Click OK to confirm this. All checked stand package combinations should have a 100% bar displayed for run status. If an error is displayed (usually at the beginning of the run attempt) indicating that there were "no trees in the cut list", this may indicate a number of potential problems—to find out which

one, check the log file written to the user/temp folder. Sometimes, this error generates due to an incomplete GIS workflow (with yarding distance not yet specified in master.plot).

4. the data generated by Processor will be stored in processor/[scenario_name]/scenario_results.mdb in two tables:
   - tree_vol_val_by_species_diam_groups, which contains, for each stand, silvicultural sequence, and simulation cycle, the volume, mass and value of collected chip (non-merchantable) and merchantable wood and the volume and mass of cut and scattered (brush-cut) wood, per acre, and placeholder—whether a no cost record is inserted for cycle 1 due to no activity in that cycle (necessitated by BioSum's internal architecture);
   - harvest_costs, which contains, for each stand, silvicultural sequence and simulation cycle, (1) the complete on-site cost in dollars per acre for the sequence *incurred in that cycle*, inclusive of harvest, brush-cutting, chipping and move-in costs, as well as any supplemental costs such as surface fuel abatement via fire or mastication, but *excluding* transportation from forest to processing facilities, (2) the harvest cost in dollars per acre, inclusive of harvest, brush-cutting, chipping and move-in costs, (3) chipping costs broken out separately, (4) equipment move-in costs broken out separately and some housekeeping flags such as (5) placeholder—whether a no cost record is inserted for cycle 1 due to no activity in that cycle (necessitated by BioSum's internal architecture), (6) override—whether harvest specifications used as input to OpCost had to be modified for parameters to be within valid ranges for the equations embedded in that model, and (7) any warning messages generated during OpCost operation. Other columns are deprecated (obsolete) as of OpCost 10.
   - Intermediate data used to produce the harvest_costs table can be found in the OpCost folder, which contains one database per variant-silvicultural sequence combination, named by OpCost version used to calculate harvest costs, variant, sequence, prescriptions, and date and time stamp (so that harvest cost results from sequences processed earlier are preserved in the event these sequences are re-processed). These databases,

which can be useful for debugging/quality assurance and/or for evaluating alternative harvest systems worth considering, contain 2 or 3 tables each: an opcost_input table, with each row containing cut list metrics calculated by BioSum for a single stand and year of entry, an opcost_output table, containing estimated harvest costs and, if OpCost generated errors, then an opcost_errors table, containing the input data for stand-year combinations that did not successfully process in OpCost.

5. If additional variant/sequence combinations need to be processed, they can be selected in this form, and processing re-initiated. Any of the processor tabs can also be accessed, to inspect or edit inputs. When done with processor operations, click **<Close>** to return to BioSum Manager**.**



Run Processor Scenario

☑ Process Low Slopes ☑ Process Steep Slopes

Harvest Cost Options: □ FRCS ☑ OPCOST

	FVS Variant	RxPackage	Run Statu		TreeVolValRecordCount	HarvestCostRecordCount	TreeCutListRec...
☑	BM	001			1251	353	> 0
□	BM	002					> 0
☑	BM	003			1084	330	> 0
☑	BM	004			1449	534	> 0

FIA Biosum

Done

Figure 5.22 – Processor scenario successfully run with three variant/rxPackage combination.

Citations

Fight, R.D., B.R. Hartsough and P. Noordijk. 2006. Users guide for FRCS: fuel reduction cost simulator software. Gen. Tech. Rep. PNW-GTR-668. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 23 p

Running OpCost in Stand-alone mode (*Advanced Topic*)

The OpCost R script was designed to be called by BioSum as a command window process spawned from BioSum that repeatedly runs R, once for each combination of variant and silvicultural sequence, supplying this script and the appropriate input/output database file name as parameters. However, as of version 10.1.5, OpCost can also be run in stand-alone mode from within the R or Rstudio environment by loading the OpCost script and editing to specify file names, with full paths for:

1. the reference database containing harvest system and harvest machine parameters,
2. the database containing OpCost inputs,
3. the database to which OpCost outputs should be written (can be the same as #2),
4. the folder to be used for writing graphics output, if that option is enabled.

Stand-alone OpCost has many potential uses, including, for example:

- Quality Assurance- are the cost estimates reasonable?
- Experimenting with the cost implications of different harvest systems;
- Building graphical summaries of the distribution of machine times, by equation and tree size class;
- Generating harvest cost estimates for purposes unrelated to analysis within the full BioSum framework;
- Building a “testbed” input file to compare and contrast the effects of tree size, tree count, slope and yarding distance on operations cost under different harvest systems.

Open the OpCost R file (which may follow the naming convention OpCost_10_1_5.R or just 10_1_5.R) in R or Rstudio; then edit the code block containing file and path information—this can be found between lines 37 and 49 – to point to the opcost_input database, output database, opcost_ref database and graphic output folder. Make sure that all of these files and folders already exist on your computer (if writing output to a different database than the one that contains the OpCost input, you will need to not only specify a database name but also create an empty Access .accdb file). If using the graphics system and wanting to customize that output, it may be desirable to tweak graph features such as axis limits and graphics file type to save to.

As OpCost is distributed with BioSum, the graphics generating code section is commented out (with a “#” in position 1 of every line) because we do **not** want to run that code when running BioSum (it would add greatly to the time and disk space usage, and in batch mode, would overwrite the most recently generated graphics files for each variant/silvicultural sequence, in turn).

To include graphics output when running OpCost in standalone mode, just select/highlight with mouse (in Rstudio) lines 587-697. Then press ctrl-shfit-C and to toggle the comment character (#) off so that this code will run. This enables the graphics module that generates box and whisker plots for all harvest machines for the analyst specified harvest system for all modeled stands for each entry as well as for all harvest machines across all harvest systems that OpCost supports. To disable graphics generation, select the same lines and press ctrl-shfit-C again and it will restore the # character at the beginning of each line, turning all these lines into unprocessed comments.

Customizing Harvest Cost Estimation (*Advanced topic*)

As described earlier, OpCost is a cost-estimation framework that includes a "starter set" of parameters primarily describing 11 harvest systems by the logging machines that make up a system, quantifying the expected productive machine hours required by each machine in a harvest system to complete the work on one acre, and calculating the cost of completing that work on one acre. Most users will not need or want to modify OpCost. However, some will. This section provides an overview of how OpCost works and how such customization can be undertaken.

The redesign of OpCost in 2018 that led to a code structure that moved virtually all equations, parameters and assumptions about the machines that comprise a harvest system out of the OpCost R code and into Access (or .CSV) data tables. This exposes virtually all assumptions and calculations into an easily readable form where they can be inspected, verified and revised if needed, and provides access to the cost per machine hour parameters so that local or more current values can be entered if desired. It also opens the potential to add additional machine equations, machine types and/or harvest systems to OpCost by editing the contents of tables in the opcost_ref.accdb file that BioSum's installation places in "C:\Program Files (x86)\FIA PNW Portland Forestry Sciences Lab\FIA Biosum 5.8.8\db\".

OpCost's four parameter tables describe harvest systems as to equipment types used (opcost_harvestsystem_ref); identify particular equations to associate with each of those equipment types (opcost_harvestequation_ref); contain the algebraic representation of those equations, the units of the calculated results, a conversion equation for translating the results to productive machine hours (PMH) per acre, and a limit statement specifying any boundary conditions that govern application of the equation— for example, if the data on which the equation was based were collected only for harvests of trees less than a specified diameter (opcost_equation_ref); and applicable costs per machine hour (opcost_cost_ref). It is critical to remember that all data, including names of variables, machines and harvest systems, must be absolutely consistent with regard to spelling, capitalization and punctuation including spaces (if any) in opcost_ref and in the OpCost input database tables as R is a case-sensitive language.

The last of these, opcost_ref, is the most straightforward to modify (Figure XX). The DefaultCPH value of $210.10 for the FellerBuncher in this example, is the cost per machine hour that will be applied to machine time estimated by OpCost. The other, state-specific values for CPH were considered applicable for those states circa 2016 and can be copied over to the DefaultCPH column for a more localized estimate. These state specific columns are not processed by OpCost so can be used to warehouse values for any state or region; moreover, their column names can be edited as needed (e.g., to CaliforniaCPH) since they are only used to store data that the analyst will ultimately need to copy over to the DefaultCPH column for the data to take effect in an OpCost simulation. The MoveInCostMultiplier is an algebraic expression, applied to DefaultCPH for the machine, using variables defined in OpCost, to represent the time required for the machine to be unloaded and setup at the operations site. The MoveInCostLowBoy is also an algebraic expression for the cost of transporting logging equipment to the site where treatments will be applied. For this FellerBuncher, a move-in cost will be calculated as 0.6533 hrs times the unit cost of 210.10 dollars/hr divided by the assumed area, in acres, treated at one location (yielding $/ac) **plus** the move-in time (hrs) times 100 $/hr divided by assumed area, in acres, giving a second term in $/ac. If the equipment to perform the operations are transported from an hour away (Move_In_Hours=1) and a harvest area of 80 acres is assumed, then the move-in costs for the feller-buncher calculated by OpCost will be ((210.10 * 0.6533) + 100)/80 = $2.96/ac. The 0.6533 hours is approximately 39 minutes. For some equipment, such as a skyline system that needs to be positioned, anchored and tested before operations can begin, it may be appropriate to specify a longer setup time for calculating this MoveInCostMultiplier.

Machine	FellerBuncher
DefaultCPH	210.1
IdahoCPH	210.1
WashingtonCPH	190.1
OregonCPH	175.1
MoveInCostMultiplier	0.6533/Harvest_area_assumed_acres
MoveInCostLowBoy	(Move_In_Hours*100)/Harvest_area_assumed_acres

Figure XX. Data from one row of opcost_cost_ref

Modification of other tables should not be undertaken casually, or without expectation of allowing ample time for empirical testing and quality assurance of the changes made. While some analysts will no-doubt imagine other modifications that we have not yet considered, this documentation covers the three that we view as the most likely modifications analysts might attempt:

1. Modifying (or adding or removing) equations for particular machine types
2. Adding a new machine type
3. Adding a new harvest system

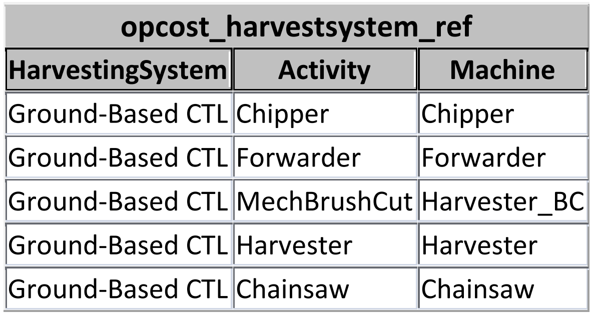
Modifying equations

FRCS contained a comparatively large number of equations per machine type. Sometimes the equations differed as to the scale of the machine (e.g., different equations for small or large skidders), but usually, the equations were for the same general kind of machine operated in different contexts (e.g., of slope and yarding distance) and/or tree harvesting burden (e.g., small vs large diameter trees, primarily hardwoods vs primarily conifers, high or low trees per acre harvested, etc.). By estimating with different equations and calculating the mean estimated time required for that machine's work on an acre, it was thought that a more robust estimate would result. However, in reality, there is likely one equation that best represents a particular situation (though which equation has that property is often unknown), and in essence diluting the most valid results of that one best equation by averaging them in with the results from several other equations that are less well fit to the situation, may not lead to greater accuracy.

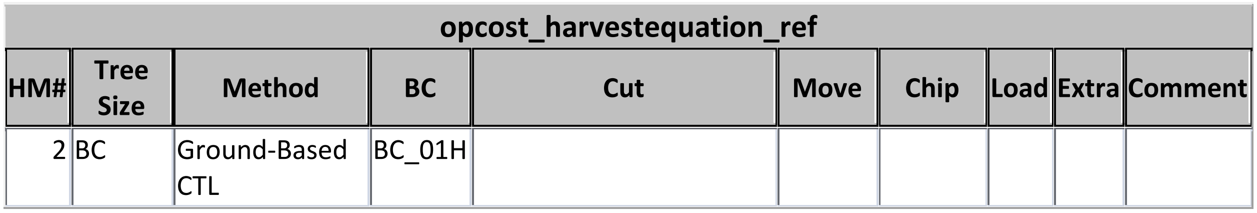
The current version of OpCost has far fewer equations per machine than did FRCS, in most cases.

that we envision at this time, and the ones that we will address via this documentation, are

opcost_harvestsystem_ref



opcost_harvestsystem_ref		
HarvestingSystem	**Activity**	**Machine**
Ground-Based CTL	Chipper	Chipper
Ground-Based CTL	Forwarder	Forwarder
Ground-Based CTL	MechBrushCut	Harvester_BC
Ground-Based CTL	Harvester	Harvester
Ground-Based CTL	Chainsaw	Chainsaw



opcost_harvestequation_ref									
HM#	**Tree Size**	**Method**	**BC**	**Cut**	**Move**	**Chip**	**Load**	**Extra**	**Comment**
2	BC	Ground-Based CTL	BC_01H						

opcost_harvestequation_ref									
HM#	Tree Size	Method	BC	Cut	Move	Chip	Load	Extra	Comment
2	CT	Ground-Based CTL		HAR_04C, HAR_05C, HAR_08C	FOR_06	CHIP_02			
2	SL	Ground-Based CTL		HAR_04S, HAR_05S, HAR_08S	FOR_06	CHIP_01			
2	LL	Ground-Based CTL		SAW_03L	FOR_06	CHIP_01			

opcost_equation_ref

EquationID	Name	Machine	Size	Equation	Units
HAR_04C	jirousek	Harvester	Chip	60.711 * ((twitchVol_ct)^0.6545)	m^3/PMH
HAR_04S	jirousek	Harvester	Small	60.711 * ((twitchVol_sl)^0.6545)	m^3/PMH
HAR_05C	karha	Harvester	Chip	0.288 + (0.1004 * ((twitchVol_ct)/0.001)) + (-0.00008*((twitchVol_ct)/0.001)^2)	m^3/PMH
HAR_05S	karha	Harvester	Small	0.288 + (0.1004 * ((twitchVol_sl)/0.001)) + (-0.00008*((twitchVol_sl)/0.001)^2)	m^3/PMH
HAR_08C	klepac	Harvester	Chip	24.796 + 0.331419 * dbh_ct ^ 2	sec/tree
HAR_08S	klepac	Harvester	Small	24.796 + 0.331419 * QMD_SL ^ 2	sec/tree

EquationID	HoursPerAcreConversion	LimitStatement
HAR_04C	totalVol_ct/result	twitchVol_ct<1.1
HAR_04S	totalVol_sl/result	twitchVol_sl<1.1
HAR_05C	totalVol_ct/result	twitchVol_ct<1.25
HAR_05S	totalVol_sl/result	twitchVol_sl<1.25
HAR_08C	(Chip.tree.per.acre * result)/60/60	dbh_ct<21
HAR_08S	(Small.log.trees.per.acre * result)/60/60	QMD_SL<21

EquationID	OldTimePerAcreConversions	OldE
HAR_04C	ifelse(twitchVolM(m)<1.4, (totalVolM(m)/jirousekHar(m)), NA)	60.711*(twitchVolM(
HAR_04S	ifelse(twitchVolM(m)<1.4, (totalVolM(m)/jirousekHar(m)), NA)	60.711*(twitchVolM(
HAR_05C	ifelse(twitchVolM(m)<.0, (totalVol(m)*0.0283168)/karhaHar(m), NA)	0.288+(0.1004*(m$" 0.00008*(twitchVolM
HAR_05S	ifelse(twitchVolM(m)<.0, (totalVol(m)*0.0283168)/karhaHar(m), NA)	0.288+(0.1004*(m$" 0.00008*(twitchVolM
HAR_08C	((klepacHar(m)*treesRemoved(m))/60)/60	24.796+0.331419*(db

HAR_08S	((klepacHar(m)*treesRemoved(m))/60)/60	24.796+0.331419*(db

Outline

Designed to be controlled by ref tables in opcost_ref.accdb

Explain what is in each of the 4 tables opcost_harvestsytem_ref, opcost_equation_ref, opcost_harvestequation_ref and opcost_cost_ref and how they are used.

Explain how to add a harvest system

Explain how to drop an existing harvest equation from a system

Explain how to add a harvest equation and add it to a system