Using TIPSY 4.3 and FAN$IER in Forests for Tomorrow (FFT) Return on Investment (ROI) Calculations

Including recommended approaches to various scenarios

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Introduction to TIPSY version 4.3 and FAN$IER

TIPSY version 4.3 includes a new economic analysis program called FAN$IER, which replaces the TIPSY ECONOMIST found in earlier TIPSY versions. In addition to performing standard economic analyses, FAN$IER incorporates a number of features specifically designed to support return-on-investment (ROI) calculations for the Ministry's Forest for Tomorrow (FFT) program. FAN$IER replaces FFT's IRR-Workbook (MS-Excel application), which relied on TIPSY ECONOMIST output.

TIPSY changes affecting FFT

Lower initial density limits
Natural disturbance mortality (e.g., fire, disease, and insects) can reduce stand density well below that supported by earlier versions of TIPSY. TIPSY 4.3 supports initial densities down to 69 stems/ha (previously 278). This equates to an average inter-tree distance of 12 meters (previously 6).

New lumber outputs
Users can now select among three (3) types of lumber outputs in TIPSY and FAN$IER:

1. Pre-adjustments: This is the default for FFT use. All lumber grades (Clear, Select Structural (SS), #1, #2, #3, #4) with no juvenile wood adjustments (degrade). Equivalent to TIPSY 4.2 lumber outputs (erroneously labeled #2 and Better).
2. #2 & Better: Just lumber grades #2 and better (omitting #3 and #4) with no juvenile wood adjustments (degrade).
3. JW adjusted: This new feature is still considered tentative by the developers, and only suited for educational purposes. At low stand densities, crown lift is delayed prolonging production of lower-valued juvenile wood. Lumber grades have been adjusted (degraded) based on the TASS-predicted percentage of juvenile wood in each board. However, the adjustments do not reflect national grading standards, which only consider juvenile wood indirectly through machine stress rating (MSR). The resulting lumber value in FAN$IER is affected solely through lumber grade reductions (degrade).

Slight changes to log and lumber profiles
Stand volume predictions (m^3/ha) have changed very little between TIPSY 4.2 and 4.3. However, log and lumber profiles have changed due to changes in the bucking, sawmilling, and grading software used with TASS to produce the TIPSY database.   This, in turn, may have a slight effect on IRR.

FAN$IER changes affecting FFT

Completely new look and feel
The FAN$IER interface is completely different from those of the TIPSY ECONOMIST and FFT's IRR-Workbook, but it has the same basic functionality, and more. Unlike the IRR-Workbook, FAN$IER is a stand-alone program that is fully integrated with TIPSY. FFT users no longer have to manually extract and transfer data. Users can document, save, and submit their individual FFT projects as FAN$IER (.FNS) files, along with associated TIPSY (.TIP) files. This document contains a quick-start guide to FAN$IER for FFT users. Online tutorial videos will be available, as well.

Default costs (and prices)
FAN$IER contains the same default cost values previously incorporated in the TIPSY ECONOMIST. These costs were last updated in 2006 using historic 10-yr averages derived from Revenue Branch data. Subsequent updates were prevented by reductions in the scope of Revenue Branch data collection since 2006. In order to maintain an appropriate relationship between costs and prices, lumber and log price defaults have been maintained at corresponding 2006 values (historic 10-yr averages). In general, no changes should be made to these defaults for FFT use. However, some default costs may be overwritten to reflect actual (expected) FFT-funded treatment costs.

Support for complete stand replacement
FAN$IER incorporates multiple options for early stand replacement. E.g., net harvest revenues from the existing stand can be included, along with net harvest revenues from the replacement stand, in the calculation of incremental-IRR.

Incremental-IRR calculation
FFT uses internal rate of return (IRR), specifically incremental-IRR, to assess ROI. FAN$IER calculates incremental-IRR by two methods, including one closely approximating the IRR-Workbook method. FAN$IER will also ignore sunk costs incurred before the "Age at Base Year" specified by the user.

Pre-commercial thinning (PCT)
FAN$IER addresses one of two cost issues that previously lead Ministry silviculture investment programs to avoid using the TIPSY ECONOMIST in ROI calculations for PCT. Specifically, based on data from FPInnovations, FAN$IER incorporates a new (non-default) tree-to-truck cost option (FPI test) that is sensitive to larger piece-size. A similar option affecting milling costs is anticipated in a future FAN$IER release.

Quick-start Guide to FAN$IER for FFT users

Tutorial videos are available online that supplement this quick-start guide.

Step 1: Produce TIPSY runs for two regimes

Experienced TIPSY users will find version 4.3 behaves just like 4.2. New TIPSY users may wish to review the TIPSY tutorial video online.

Two separate TIPSY runs (.TIP files) must be created: One for the untreated regime (base case) reflecting the do-nothing scenario, including any yield impacts from natural disturbance (fire, disease, insects, etc.). The second regime reflects the expected outcomes from the proposed (remedial) treatment(s). Later sections in this document outline suggested strategies for modelling various natural disturbances and remedial treatments with TIPSY.

FFT mandatories:
- Set TIPSY Table Specs for both regimes to report in relation to age, ranging from 0 (zero) to an upper-bound well beyond the MAI (merch 12.5+) culmination age of the longest regime (roughly 20yrs longer, by trial and error if necessary), in steps of 1 (one) year.
- Give each .TIP file a unique, descriptive filename that includes a FFT project identifier and a stand regime identifier (e.g., 93K-012-034_untreatedA.tip; 93K-012-034_treatedA.tip).

Step 2: Send both TIPSY runs to FAN$IER

Clicking the [$] button sends the regime displayed in the active (front) TIPSY window to FAN$IER; it does not matter which view is displayed (stand description, yield table, mortality table, etc.). FAN$IER launches automatically as a stand-alone program and TIPSY remains open in the background. Go back to TIPSY, bring up the second regime, and send it to FAN$IER the same way.

Confirm that both regimes appear in the Regime drop-down list.
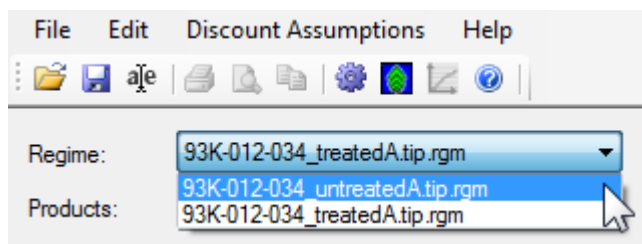
Step 3: Configure both regimes in FAN$IER

Each regime must be configured separately, but it does not matter which regime is configured first. Select a regime to configure from the Regime drop-down list (above).

MAIN SCREEN SETTINGS

The content and settings visible on FAN$IER's main screen, and its tabs, refer to the currently selected regime.

> Unless explicitly stated otherwise,
> FAN$IER defaults are mandatory for FFT.
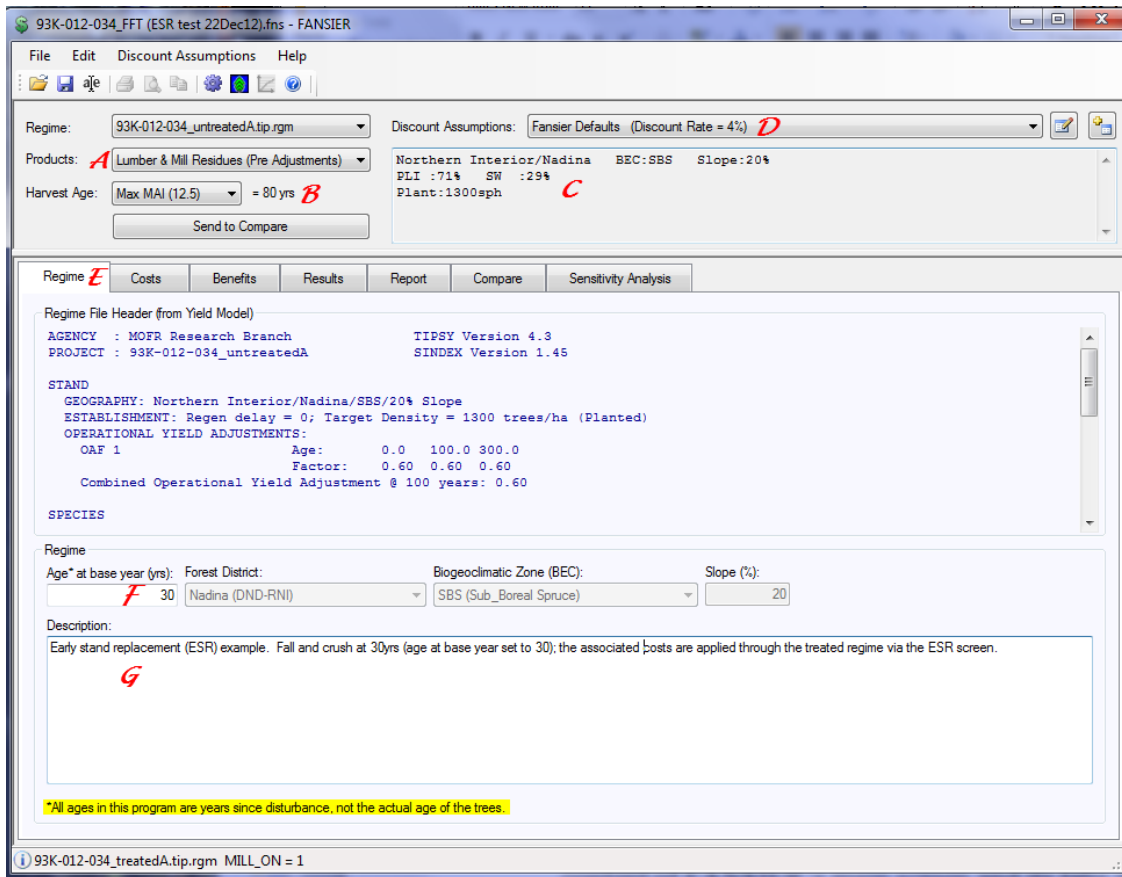
The key main screen features labeled above are as follows:

A. **Products:** Defines the product used for revenue calculations. Defaults are logs on the coast and lumber in the interior. FFT projects in the Interior use "pre-adjustments" lumber, the FAN$IER default.

B. **Harvest Age:** Defines the regime rotation length used in economic calculations and comparisons. Default is Max MAI (12.5), i.e., culmination of mean annual increment for Merch 12.5+ volume. This is the harvest age definition used in FFT ROI calculations.

C. Brief regime summary for reference (cannot be edited).

D. **Discount assumptions:** Access to related values; make no changes for FFT.

E. **Tabs:** Each tab displays a different view of the regime's economic inputs and outputs. More detail to follow. The Cost and Compare Tabs are of particular importance to FFT users.

F. **Age at base year:** Defines the base year for economic calculations (IRR, NPV, etc). Sunk costs (and revenues) before this age are ignored. In most FFT scenarios, this must be reset by the user to correspond with stand age at the time of FFT treatment.   Forest District, BEC, and Slope

values to the right define cost and benefit defaults. They are passed from TIPSY and can only be edited there.

G. **Description:** Space for FFT-required documentation of TIPSY and FAN$IER modelling strategies. Be specific enough to enable someone else to follow your logic and recreate your work.

COST TAB

FAN$IER's default costs are normally used for FFT projects. The one exception being costs specific to FFT (remedial) treatments, when they are known. Activity categories marked with an "X" (e.g., fertilization above) cannot be accessed because they were not applied to the regime in TIPSY. Cost defaults for each activity can be overriden by clicking on the activity title and selecting the user-specified method. Sunk costs scheduled at ages less than the specified "age at base year" will be ignored, so their values do not matter.

User-specified costs require an age (for scheduling), brief title (for reports), rate (cost/ha), and rate reference year (i.e., the calendar year associated with the rate estimate/quote). The latter is used to adjust costs to 2006 dollars (the basis for all FAN$IER analyses) assuming an annual inflation rate of 2%.

The Other Silviculture Costs category (arrow above) accomodates activities without a specific cost category elsewhere. Additional activity blocks can be created by clicking the "+" in the left margin.

BENEFITS TAB

Tables display the quantity and value of the selected **Products** at the selected **Harvest Age** for the selected **Regime**. Tables automatically update when any of these selections are changed. Unit prices can be overridden by the user either by adjusting the individual unit prices, or by applying price adjustment factors. No changes are allowed for FFT use.

RESULTS TAB

This table provides a simple listing of various (undiscounted) economic outputs by age based on current economic settings for the regime. The table is automatically updated when settings are changed.

REPORT TAB

Extensive tables documenting both inputs and outputs in report format, based on current economic settings for the regime. The table is automatically updated when settings are changed.

SENSITIVITY ANALYSIS TAB

This table provides a sensitivity analysis for the selected regime. It reports SV, NPV, or IRR values for ±10% changes in various costs and benefits.

In the interior, the "JW Adjusted" lumber Products option could replace the IRR-Workbook's "Value Adjustment for Stand Density" in sensitivity analyses. But, FAN$IER provides no equivalent juvenile wood adjustment for logs on the coast. On the coast, users may wish to apply the IRR-Workbook value adjustment using FAN$IER's price adjustment factors. The IRR-Workbook multiplier is a simple function. It equals 1.0 when stand density is above 80% of the appropriate stocking target. Below 80%, it declines linearly to 0.4 at 20% of the stocking target. Both adjustment methods are tentative at best, and should be used and interpreted with caution.

Step 4: Check FFT Results In the Compare Tab

The Compare tab contains features of particular importance to FFT:

- Side-by-side comparison of two regimes, e.g., base-case (untreated) and treated-case regimes. Individual regimes are sent one-at-a-time to the Compare tab using the "Send to Compare" button on the main screen. Symbols in the regime column headings allow the user to delete columns (x) and switch their order (←).
- Compare features enable users to configure comparisons for both basic FFT scenarios: existing stand treatment (default) and early stand replacement. Refer to the section "Comparing FFT Treatment Options" for more detail.
- IRR is reported here for assessing FFT ROI. The following section provides important detail about IRR.

Interpreting FAN$IER's various IRR values:

FFT uses a 2% IRR threshold, specifically incremental-IRR, to assess ROI. The TIPSY ECONOMIST did not calculate IRR, which prompted IRR-Workbook development. FAN$IER calculates and reports three (3) different types of IRR:

1. IRR: FAN$IER always reports an independent (non-incremental) IRR for each regime, but this is not the IRR used for FFT ROI.

Optionally, FAN$IER also calculates two types of incremental-IRR and reports them in the Compare table only. Incremental-IRR is similar in concept to the IRR above, but it is calculated from the difference in costs and revenues between the two regimes (ignoring sunk costs when directed).   Both types of incremental IRR are toggled on and off independently through the main EDIT menu.   Negative incremental IRR values are not reported. Instead, a note appears at the bottom of the Compare table.

2. FFT IRR: This closely approximates the incremental-IRR method in the IRR-Workbook. Although it is not evident within MS-Excel, IRR calculations have more than one mathematical solution (root) in certain situations. In FFT terms, this occurs whenever the rotation length of the treated-case regime is the shorter than that of the base-case regime. Mathematically both IRR solutions (roots) are equally (in)valid, and neither is necessarily correct. Due to MS-Excel limitations, the IRR-Workbook only reported one root, but FAN$IER reports both to alert the user.

3. Reinvestment IRR: To address problems associated with different rotation lengths, FAN$IER developers introduced an alternative method for computing incremental-IRR. Although the method has theoretical problems of its own, it provides a comparison when the FFT IRR is suspect. In this method, net harvest revenues from the shorter of the two rotations are reinvested (discounted forward) at a fixed interest rate (2% default), until the longer regime's harvest date. In effect, equalizing the two investment periods (rotation lengths).

NOTE: When rotation lengths are equal, the two incremental-IRR methods produce the same (correct) answer. In all other cases, increment-IRR values warrant cautious, conservative interpretation.

Navigation and other Tips

1. FAN$IER provides a number of opportunities to change regime settings, making management and comparison of different regimes flexible and efficient. The entire main settings block above the tab line remains visible and functional when the Compare tab is open. Normally, the main settings block and Compare column headers are entirely grey. In this state, changes to the main settings will not affect the regimes (columns) currently displayed in Compare. The main settings can still be used to select or re-configure a regime before sending it to the Compare tab.

    However, by clicking on an individual regime column heading in the Compare tab, the column heading and main settings block will both turn orange (see below). This indicates that changes in the main settings block will now affect the orange-highlighted regime in the Compare tab. Clicking once again on the column heading turns off this feature.

n/c	n/c		n/c
n/c	[📕] PDF Report		n/c
n/c	[💾] Save Report		n/c
n/c	[📗] CSV Report		n/c
n/c	[🖨] Print Report		n/c
n/c	[🔍] Preview Report		n/c
2.13			1.91
3.28	[📋] Copy		3.08
3.74	[🗔] Select All		3.56
3.88	[🖼] Copy as Image		3.72
3.93	3.93		3.77

2. Options for printing and saving reports.

Right-clicking within the body of an individual tab table brings up a menu (left) providing several export and printing options.

3. Under EDIT in FAN$IER's the main menu, there is a toggle to "Show Calendar Year". Checking this option displays calendar year (e.g., 2013) in parentheses alongside ages in the various output tabs, including Compare. Calendar year is linked to stand age as follows:

Calendar year at stand age 0 =
   present calendar year (from user's computer clock)
   minus age at base year (set by user in FAN$IER)

4. Note, within TIPSY and FAN$IER, stand age refers to years since the stand-replacing disturbance (e.g., harvest, fire, etc), rather than tree age. This corresponds to ages definitions commonly used in timber supply analyses.

Configuring the Two Basic FFT Scenarios in FAN$IER

A simulation of the existing damaged stand (base-case regime) must be compared to post-treatment yield expectations (treated-case regime) in order to evaluate ROI. The Compare table will report incremental-IRR once the two regimes are configured properly; this include setting an appropriate "age at base year" to ignore sunk costs.

FFT scenarios fall into one of two general types requiring different simulation and comparison methods:

Existing Stand Treatment Scenario
In this scenario, enough of the existing stand survives to justify retaining the residuals and applying treatment(s) to supplement stocking (e.g., fill planting) and/or enhance growth (e.g., fertilization, etc; see Appendix B).   Two TIPSY regimes (.TIP files) are required for this scenario:

Base-case Regime: The untreated (do-nothing) regime incorporating damage impacts and natural regeneration assumptions.

Treated-case Regime: The run reflects expected treatment effects on stocking and growth. Some treatments (e.g., fertilization) are explicitly supported in TIPSY. Other treatments (e.g., fill planting) require user intervention to reflect their impact on future yield.

Existing Stand Treatment Timeline Example

- Base-case regime harvest
- Treated-case regime harvest
- Age @ base yr = age at treatment
- Age @ base yr = age at treatment
- Natural disturbance
- Existing stand establishment

Early Stand Replacement Scenario
This scenario is characterized by heavy mortality and expectations of insufficient natural regeneration. The existing heavily-damaged stand will be destroyed or harvested (depending on residual value) and then regenerated from bare-ground. Two TIPSY regimes (.TIP files) are required for this scenario:
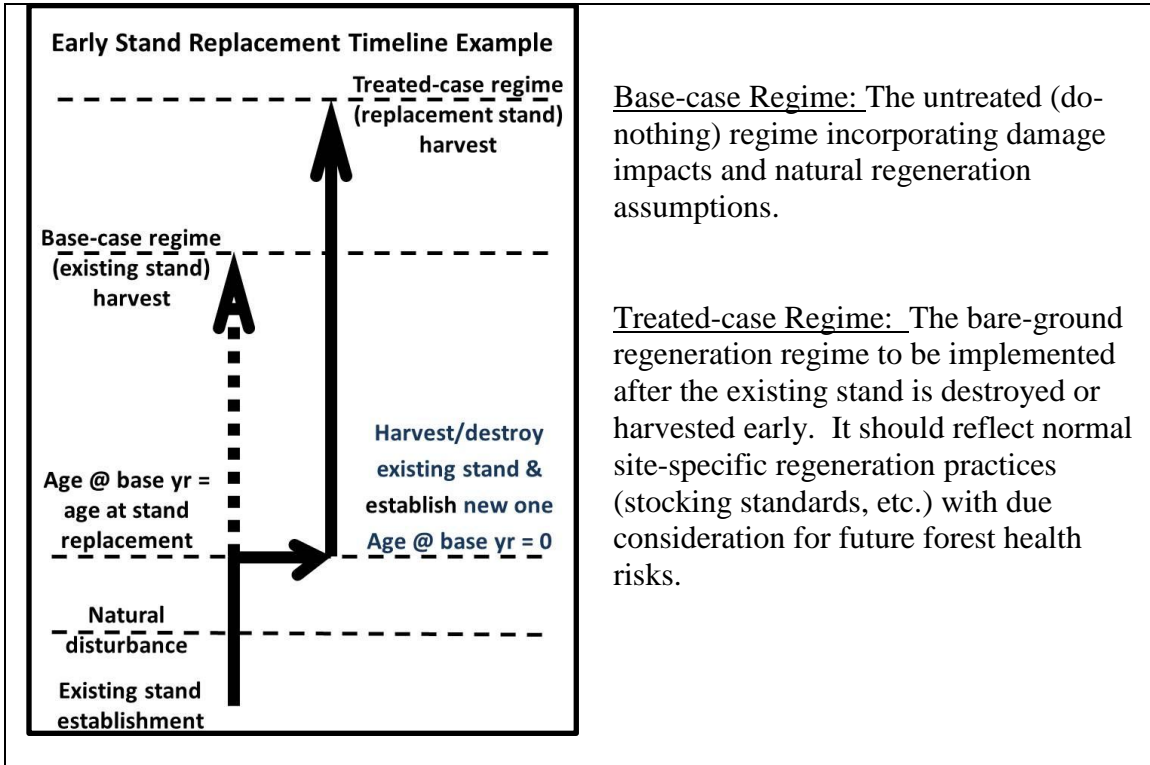
Early Stand Replacement Timeline Example

Treated-case regime
(replacement stand)
harvest

Base-case regime
(existing stand)
harvest

Age @ base yr =
age at stand
replacement

Harvest/destroy
existing stand &
establish new one
Age @ base yr = 0

Natural
disturbance

Existing stand
establishment

Base-case Regime: The untreated (do-nothing) regime incorporating damage impacts and natural regeneration assumptions.

Treated-case Regime: The bare-ground regeneration regime to be implemented after the existing stand is destroyed or harvested early. It should reflect normal site-specific regeneration practices (stocking standards, etc.) with due consideration for future forest health risks.

Early stand replacement scenarios require additional settings in FAN$IER. After sending both regimes to the Compare tab, open the Early Stand Replacement dialogue box (below) by clicking the "Early Stand Replacement" cell in the <u>treated-case</u> column of the Compare table. Early harvest costs and benefits are financially associated with, and reported with the treated-case. Early harvest costs (logging and milling combined) are reported under silviculture costs.

A. This is the default setting, which applies to FFT Existing Stand Treatment scenarios. FFT Early Stand Replacement scenarios use option C.

B. This option does not apply to FFT scenarios. It derives early harvest costs and benefits from the selected Regime, the base-case by default.

C. FFT Early Stand Replacement scenarios follow this protocol:

    a. First, determine if ROI supports pursuing a special timber sale[1] by setting the cost (to FFT) and benefit both to zero.

    b. If the timber sale option fails, determine the ROI of FFT-funded stand destruction (knockdown) by entering the expected knockdown cost and leave benefits at zero.

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[1] FFT-BCTS MOU: http://www.for.gov.bc.ca/hcp/fia/landbase/fft/20120709111855.pdf

Principles and Techniques for Simulating Natural Disturbance Impacts and Remedial Treatments

TIPSY has no tools for simulating the impacts of specific biological natural disturbance agents, other than Armillaria root rot (ICH Fdi only). To accommodate others, <u>one must know how various damage agents affect stand development and understand how TIPSY operates in order to manipulate its various inputs to produce the desired effects</u>.

TIPSY Characteristics and Features

<u>Required inputs:</u>
TIPSY is a bare-ground model. This means it grows stands based solely on their establishment information (initial density, etc). It does not (directly) accept survey data (tree-list data) from established stands. Simulating existing stands with TIPSY involves guessing an initial density (etc) that approximates current stand conditions.

TIPSY contains an existing-stand start-up routine (accessed via the "Density" button in Stand Specifications) which automates some of the guesswork. But, it only reflects mortality factors inherent in TIPSY, i.e., inter-tree competition. Iterative trial and error is the alternative.

> At the time of writing, a separate project was underway to develop tools for initiating TIPSY with silviculture survey data (e.g., FFT surveys, RESULTS, etc). Check TIPSY and FFT websites for updates.

<u>Stand structure and species:</u>
Fundamentally, TIPSY provides yield predictions for single-species, even-aged stands. Understanding the implications of this is crucial to adapting TIPSY to more complex stand structures.
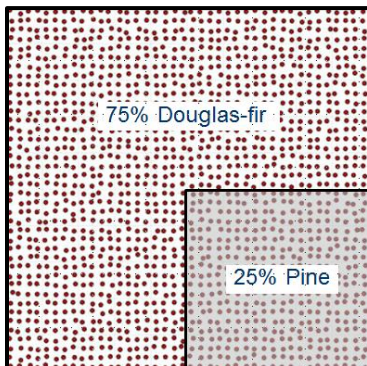
The mixed-species yields reported by TIPSY are simply area-weighted averages of individual single-species yields, as the conceptual diagram to the left illustrates (yield per ha = ¾ ha pure Douglas-fir plus ¼ ha pure pine). <u>Mixed-species predictions do not incorporate species dynamics (succession, etc.). Species composition remains constant over time.</u>

Similarly, TIPSY does not simulate multi-layered or uneven-aged stand structures. This can be overlooked if the age range is narrow. In other cases, users may opt to ignore overtopped layers that are not expected to make significant contributions to harvest yields. TIPSY's Variable-Retention (VR)

feature grows the regenerating stand, but does not grow or report retained-overstory yields. A residual overstory could be modelled independently, but it will have no biological effect on understory growth.

Natural regeneration and ingress:
Predicting the amount and timing of natural regeneration after natural disturbance is a key factor in FFT ROI calculations. <u>Since TIPSY does not predict natural ingress itself, it must rely on user estimates.</u> Because natural regeneration success is difficult to predict, several runs with different levels of natural regeneration can be produced for individual comparison with the treated stand. In this way, a risk assessment can be conducted regarding the assumed level of natural regeneration. I.e., below what level of assumed natural regeneration does early stand replacement become financially attractive?

Initial density values used in TIPSY should represent the total expected number of trees (planted trees plus natural ingress contributing to the final crop). Note, genetic gain is only applied when the planted distribution is selected. If a significant amount of natural ingress is expected (diluting genetic gain), then the natural or clumped distribution may be more appropriate, but no genetic gain will be applied.

Stocking Reductions, Spatial Distribution and Stratification:
Several methods are presented in this publication for modelling natural disturbance mortality depending on stand structure and available data. TIPSY 4.3 supports initial densities down to 69 stems/ha (previously 278). This equates to an average inter-tree distance of 12 meters (previously 6).

Natural disturbance mortality commonly affects spatial distribution, as well. For randomly distributed mortality, a reduction in density (trees/ha) may be appropriate, coupled with a shift from a "planted" to a "natural" distribution (square spacing versus random spacing). For mortality occurring in small- to medium-sized clusters (approx. 10-30 trees/cluster), a clumped distribution is available for five species (i.e., Hwc, Pli, Fdi, Sw, At). However, TIPSY only provides one clumping pattern (e.g., clump density and spacing), which could be quite different from actual conditions.

If the mortality occurs in large clumps, where a majority of both the remaining crop trees and the post-disturbance regeneration are not "edge" trees (clumps of approximately 30 or more trees), consider stratifying the disturbed and undisturbed patches. In this case, the undisturbed stratum would be simulated as if no disturbance had occurred, and the disturbed patches simulated as a newly established stand.
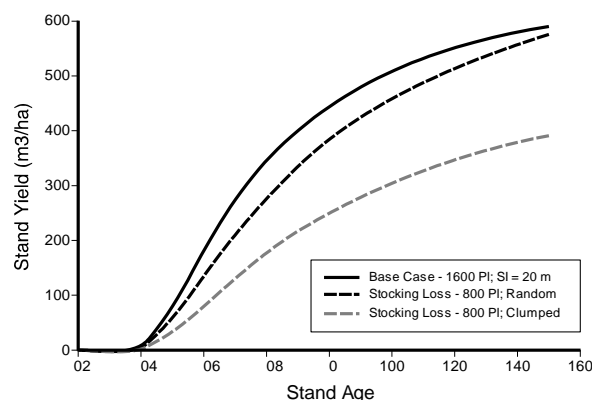
While this methodology can be very effective for simulating the impacts of a disturbance agent on yield, simulating remedial treatments can be problematic. Options for simulating the impacts of fill planting are presented in a subsequent section.

Site Index:

When the impact of a biological agent is a permanent loss of height growth potential, the effects can be simulated using a reduction in site index. However, such cases are rare.
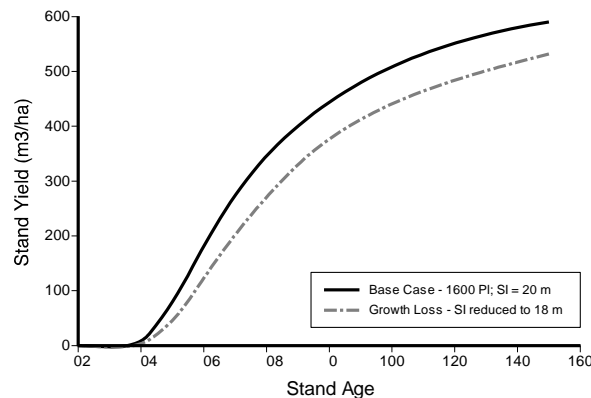
Regeneration (Regen) Delay:

When the impact of an agent is a temporary growth reduction, the effect can be simulated using a regen delay. The same stand development milestones are achieved, only at a later date. This method has been used to simulate the temporary effects of overtopping competition. It could also be used to simulate the impacts of agents that do not cause mortality (e.g., defoliators). TIPSY will not accept delays greater than 50 years. In rare cases where this is an issue, a large OAF1 (e.g., 0.50) could be applied instead.
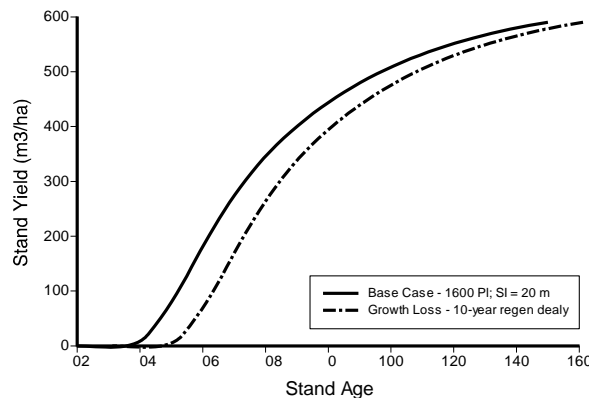
Operational Adjustment Factors (OAFs):

TIPSY offers several options for adjusting predicted yields, collectively known as Operational Adjustment Factors (OAFs). <u>Because OAFs affect both stocking and volume, they are an important tool for simulating the impacts of natural disturbances.</u> OAFs are used to adjust for a wide range of abiotic and biotic factors that cause predicted yields to differ from actual yields. In addition to its two main OAFs, OAF1 and OAF2, TIPSY allows users to create and apply custom OAFs.
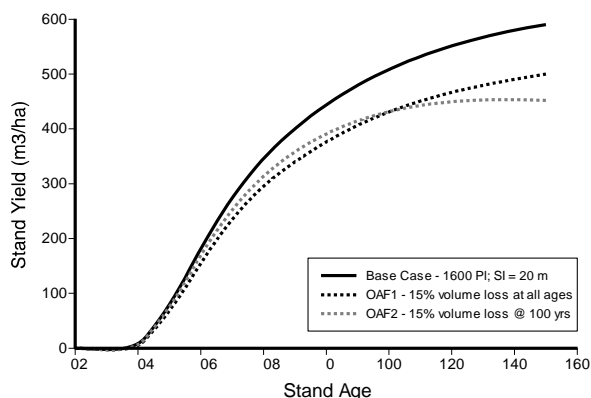
OAF1 is a simple, constant yield multiplier (i.e., 0.85 produces a 15% reduction in yield at all ages). The default (0.85) is regularly applied to reduce yields for abiotic factors, such as small patches of unmapped non-productive ground (e.g., rock and wetlands). It can also represent unstocked gaps, growing space occupied by non-commercial species, endemic losses to diseases and other pests, and low-level losses to environmental factors such as wind and snow/ice. In FFT scenarios, OAF1 could be used to represent unoccupied growing space resulting from natural disturbance mortality, as long as the contribution of subsequent ingress (in-fill) to harvest volume is assumed to be negligible.

Be aware that OAF1 does not affect mean annual increment culmination age (max MAI), the standard FFT harvest age definition. In situations where the base- and treated-case only differ by their OAF1 values, the max MAI harvest definition may produce unintended outcomes. In these cases, an alternate harvest age criteria may be more appropriate (e.g., max NPV).

OAF1 values can also be used to adjust yields upward or downward based on user-perceived yield changes not otherwise supported by TIPSY. A few examples include:

- Cases where a plantation is mostly destroyed and will be simulated as a bare ground scenario, but the advanced development of residual trees from the previous plantation will provide a small amount of extra volume. This is not the same as a complete stand replacement scenario, which has no carry-over residual volume.

- Cases where partial mortality in a plantation will be replaced with a different species of greater or lesser productivity (or greater or lesser shade tolerance).

- Cases where low level, ongoing losses are expected.

OAF2 is a progressive yield multiplier, its impact increases with age. The default (0.95) is regularly applied to account for endemic biotic factors (e.g., insects and disease) with yield effects that increase over time. OAF2 is indexed to age 100, such that the value of OAF2 equals its yield impact at age 100. OAF2 increases by 1% each year reaching its assigned value at age 100, and continues to increase by 1% each year afterwards. E.g., for an OAF2 of 0.90, the yield multiplier would be 0.99 at age 1, 0.95 at age 50, 0.90 at age 100 (the index year), and 0.80 at age 200. In FFT scenarios, applications of OAF2 in excess of the default (0.95) is likely limited since natural disturbances producing slow progressive yield losses may not meet FFT investment criteria.

Effect of OAFs 1&2 on per-hectare density and volume

1 ha; OAF = 1.0	1 ha; OAF = 0.85

0.15 ha non-productive
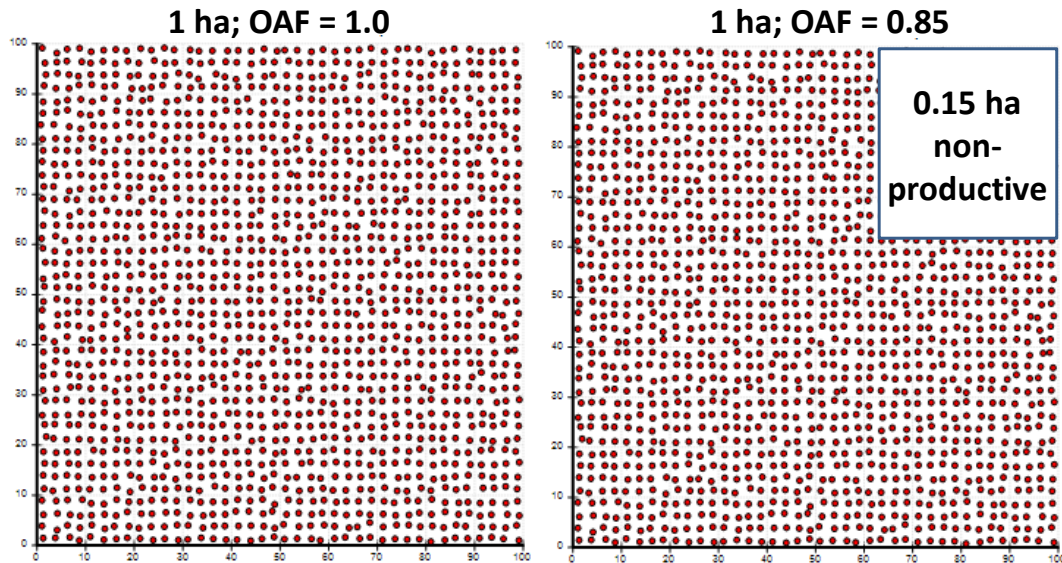
OAF1: non-productive area remains constant over time.
OAF2: non-productive area constantly increases over time.
Residual stand structure and spacing remain the same.

Custom OAFs can also be defined in TIPSY. With input from forest health expects, they can be used to model complex forest health impacts. Custom species-specific OAFs for Armillaria root rot are included in TIPSY for Douglas-fir in the ICH.

Custom OAFs also provide a workaround to the restriction preventing regular OAF1 <0.50. Only one point (age=0) is needed to define a Custom OAF1. The regular OAF1 value must then be set to 1.0 to avoid compounding the two. Refer to TIPSY HELP for a thorough explanation of Custom OAF creation.

Sensitivity Analysis:
There is often a good deal of uncertainty associated with the various inputs/adjustments discussed above. Sensitivity analysis is a means to assess the relative impact or importance of these inputs/adjustments on volume yields. Resources can then be focused on refining the inputs/adjustments that have the largest impact. Sensitivity analysis involving a particular TIPSY input/adjustment can be performed by developing multiple regimes exploring changes (e.g., ±10%) in that one item. FAN$IER's sensitivity analysis tab provides additional sensitivity analysis on costs and prices.

Estimating Volume Gains from Fill Planting (treated-case) with Two Options for Estimating Volume Losses from Juvenile Mortality (base-case)

The following four tables were developed from a series of custom TASS runs (the growth and yield model behind TIPSY) to examine a wider range of post-damage stand conditions than is possible with TIPSY alone. These tables help the user configure TIPSY runs to estimate: 1) volume loss from juvenile mortality (base-cases) and 2) volume gains from fill-planting (treated-cases). Both base-case techniques can be used in conjunction with other treatments, not just fill-planting.

Table 1. **Yield reductions resulting from partial plantation mortality, along with potential remedial growth as a result of fill planting, have been estimated using a set of custom TASS simulations. For each of lodgepole pine (top) and Douglas-fir (bottom), losses due to mortality are listed on the left hand side, and proportions of lost volume potentially regained through fill planting are listed on the right. In the example highlighted below, a lodgepole pine stand losing 25% of its trees in medium sized clumps (average diameter = 15 m) at age 14 would have its yield reduced by 19%. Fill planting this stand at age 15 would recover 65% of the lost volume, or 12.3% (0.19 x 0.65) of the non-impacted stand yield. Stands as simulated assumed a pine plantation with a site index of 22m and a plantation density of 1600 trees/ha, and a Douglas-fir plantation with a site index of 32m and a plantation density of 800 trees/ha.**

Proportion of Pl volume lost as a result of juvenile mortality related to a damaging agent - volume losses vary primarily by clump size and percent of trees killed.

Clump Size	Age at Mortality	12.5	25	37.5	50
Random Trees	4	0.02	0.06	0.12	0.20
	9	0.03	0.07	0.13	0.20
	14	0.02	0.06	0.12	0.21
19.53 m² (d = 4.98 m)	4	0.07	0.13	0.21	0.21
	9	0.07	0.13	0.21	0.21
	14	0.07	0.14	0.21	0.21
178.57 m² (d = 15.08 m)	4	0.09	0.19	0.28	0.34
	9	0.09	0.19	0.29	0.34
	14	0.09	0.19	0.29	0.34
1250 m² (d = 39.9 m)	4	0.11	0.11	0.33	0.45
	9	0.11	0.11	0.34	0.45
	14	0.11	0.12	0.34	0.45

Proportion of lost Pl volume potentially regained through fill planting - gains vary primarily by clump size and timing of mortality and fill planting.

Clump Size	Fill Plant Age	12.5	25	37.5	50
Random Trees	5	0.23	0.65	0.69	0.79
	10	0.00	0.24	0.41	0.53
	15	0.00	0.00	0.22	0.31
19.53 m² (d = 4.98 m)	5	0.51	0.75	0.78	0.72
	10	0.29	0.47	0.55	0.59
	15	0.26	0.28	0.41	0.42
178.57 m² (d = 15.08 m)	5	0.87	0.87	0.89	0.90
	10	0.71	0.74	0.79	0.81
	15	0.62	0.65	0.70	0.70
1250 m² (d = 39.9 m)	5	0.89	0.90	0.92	0.93
	10	0.79	0.77	0.83	0.83
	15	0.68	0.70	0.73	0.76

Proportion of Fd volume lost as a result of juvenile mortality related to a damaging agent - volume losses vary primarily by clump size and percent of trees killed.

Clump Size	Age at Mortality	12.5	25	37.5	50
Random Trees	3	0.03	0.07	0.11	0.19
	6	0.03	0.08	0.12	0.20
	9	0.04	0.06	0.11	0.19
19.53 m² (d = 4.98 m)	3	0.05	0.10	0.17	0.22
	6	0.05	0.10	0.16	0.21
	9	0.05	0.10	0.17	0.16
178.57 m² (d = 15.08 m)	3	0.06	0.11	0.17	0.21
	6	0.06	0.11	0.19	0.22
	9	0.06	0.11	0.18	0.21
1250 m² (d = 39.9 m)	3	0.00	0.11	0.30	0.39
	6	0.10	0.10	0.31	0.40
	9	0.10	0.10	0.29	0.39

Proportion of lost Fd volume potentially regained through fill planting - gains vary primarily by clump size and timing of mortality and fill planting.

Clump Size	Fill Plant Age	12.5	25	37.5	50
Random Trees	4	0.88	0.96	0.90	0.93
	7	0.67	0.78	0.72	0.83
	10	0.54	0.36	0.98	0.59
19.53 m² (d = 4.98 m)	4	0.46	0.75	0.78	0.82
	7	0.30	0.47	0.56	0.59
	10	0.26	0.28	0.42	0.43
178.57 m² (d = 15.08 m)	4	0.87	0.94	0.96	0.93
	7	0.76	0.87	0.88	0.87
	10	0.70	0.80	0.80	0.76
1250 m² (d = 39.9 m)	4	NA	0.98	0.95	0.96
	7	0.92	0.92	0.92	0.92
	10	0.87	0.85	0.90	0.88

Two options are presented here for using Table 1 to adjust OAF1 for estimating volume gains from fill planting.   Each option builds on a different technique for adjusting base-case yields to reflect volume losses due to juvenile mortality.

Note that TIPSY does not accept OAF1 values less than 0.50, however Custom OAFs provide a workaround. Refer to the preceding section on OAFs.

OPTION 1:   Base-case development using stocking adjustments in TIPSY to estimate volume loss.

> STEP 1:   Generate a temporary regime simulating the base-case <u>without damage</u>.

> STEP 2:   <u>Generate the base-case regime</u> using adjustments in TIPSY to estimate volume loss from damage, e.g., adjustments to initial density, regeneration method (spatial distribution), etc.

> STEP 3:   Using the two regimes above, calculate *A*, the difference in volume (Vol, Merch 12.5+) at culmination of mean annual increment (cMAI), between the undamaged (STEP 1) and damaged (STEP 2) regimes as a proportion of the damaged regime.

> **A = (Step1Vol@cMAI – Step2Vol@cMAI) / Step2Vol@cMAI**

> STEP 4:   Interpolate a value *B* from the right hand side of Table 1 that best approximates the damaged stand conditions (species x stocking loss x clumpiness x fill plant age). *B* represents the proportion of the lost volume (*A*) regained through fill planting.

> STEP 5:   Adjust the OAF previously applied to the damaged base-case in STEP 2 (Step2OAF1) in order to incorporate fill planting effects.

> **Adjusted OAF1 = Step2OAF1 * (1 + A*B)**

> STEP 6:   <u>Generate the treated-case regime</u> from the base-case regime (STEP 2) by replacing its OAF1 (Step2OAF1) with the Adjusted OAF1from STEP 5.

OPTION 2: Base-case development using Table 1 to estimate volume loss.

> STEP 1:   Generate a temporary regime simulating the base-case <u>without damage</u>. Apply the standard default OAF2 (0.95), but do not set OAF1 yet.

> STEP 2:   Interpolate a value (*C*) from the left hand side of Table 1 that matches the damaged stand conditions (species x stocking loss x clumpiness x disturbance age). Then calculate an adjusted OAF1 for the base-case that will adjust for volume loss due to damage. The default OAF1 is normally the standard default of 0.85, unless documented site conditions warrant otherwise.

Adjusted OAF1 (base case) = Default OAF1 * (1 − *C*)

STEP 3: Generate the base-case regime by applying the Adjusted OAF1
from STEP 2 to the temporary regime from STEP 1.

STEP 4: Interpolate a value (***B***) from the right hand side of Table 1 that
best approximates the damaged stand conditions (species x stocking loss x
clumpiness x fill plant age). ***B*** represents the proportion of the lost volume (***C***)
regained through fill planting. Then calculate an adjusted OAF1 to be applied to
the treated-case.

Adjusted OAF1(treated-case) =
Adjusted OAF1 (base-case) * (1 + *B**C)

STEP 5: Generate the treated-case regime by replacing the OAF1 in the
base-case regime with the Adjusted OAF1 from STEP 4.

Several caveats are required for using the values in Table 1 to simulate fill planting. These are:

- Base- and treated-case regimes produced by this method differ only by their
  OAF1 values. This means both regimes will always have the same MAI
  culmination (max MAI) age, FFT's normal harvest age definition. Because this is
  not the usual excitation for fill planting, alternate harvest age definitions may also
  be explored, e.g., max NPV.

- In its current form, the TASS model is imperfectly suited to simulating multi-
  layer stands. This limitation becomes more severe the wider the age discrepancy
  between different cohorts, and is not believed to be overly significant in these
  situations involving young stand mortality.

- A limited range of conditions were used to generate the tables – only one site
  index and one establishment density were used for each species, and planted
  (square) spacing was assumed in all cases.

- It was assumed that the same species would be regenerated as was originally
  established. It is likely that this will not always be the case in an operational
  setting, particularly if the remedial treatment seeks to avoid problems with pest
  agents that caused the original mortality. In many cases, fill planting using a
  different species may result in different volume recovery rates.

In other words, the values in Table 1 should be applied with appropriate skepticism.

Options for Simulating Dothistroma Needle Blight

Dosthistroma needle blight, caused by the pathogenic fungus *Mycosphaerella pini*, is currently having devastating impacts on lodgepole pine stands in the ICH biogeoclimatic zone of northwestern British Columbia[2].The disease attacks all ages of needles, effectively defoliating severely affected trees. With repeated attacks, tree mortality frequently occurs. Stand level impacts range from temporary growth losses to almost complete stand mortality.

In almost all cases of Dothistroma needle blight, growth losses will occur as a result of defoliation. Woods (2004)[2] documented two cases of attack in mid-rotation stands where radial growth has been significantly reduced (>65%) during periods of infestation. Such growth losses could be modeled as a 2-year regeneration delay for every three years of attack. Note that growth losses in many young stands may be more severe and of greater duration. Note also that there is a great deal of uncertainty related both to the duration of current attacks and the frequency & duration of future episodes.

In stands where little mortality is occurring, the simulation of pest effects using regeneration delays will be sufficient. Where mortality is occurring, however, there will need to be corresponding reductions in stocking and/or further regeneration delays (related to natural ingress) for the untreated stand.

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[2] Woods, A. 2004. Dothistroma in northwest British Columbia. Why There? Why Now? In Press.

Listed below are two different stand descriptions for plantations impacted by Dothistroma needle blight. Below each description is a set of modeling assumptions that might be used to simulate yields for both the untreated and treated stands.

Stand #1
- Pl planted @ 1600 trees/ha
- Stand age = 10; SI = 22
- 60% mortality, randomly distributed
- 700 trees/ha natural Hw (SI = 18), patchy distribution (60% of area); ave. age = 3
- Current attack duration = 6 yrs, another 6 yrs expected

Modeling Assumptions
- Split into two strata: with and without Hw; portion with Hw has 1167 per ha (700 ÷ 0.6)
- Assume 2-yr Pl regen delay for each 3 yrs of attack – Hw and Pl will be close to even footing on age basis – run all simulations with 8-yr regen delay
- Assume no treatment on Hw portion; stocking becomes 640 Pl, 1167 Hw
- Non-treated stocking for portion without Hw becomes 640 trees/ha Pl
- Assume fill plant with 700 trees/ha Sx on portion with no Hw; treated stocking becomes 640 Pl, 700 Sx
- Use TIPSY default SI adjustments for adding new species
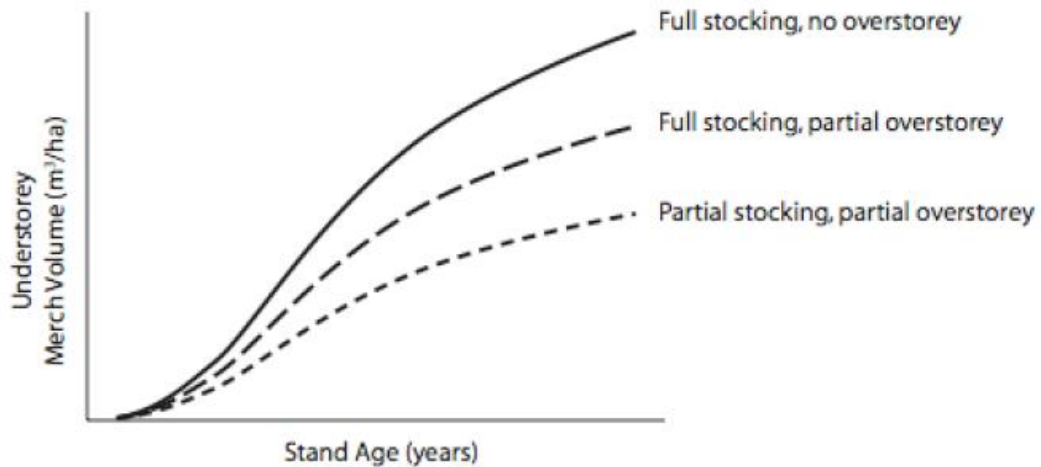
Stand #2
- Pl planted @ 1600 trees/ha
- Stand age = 10; SI = 22
- 60% mortality, randomly distributed
- Current attack duration = 6 yrs, another 6 yrs expected

Modeling Assumptions
- Assume 8-yr regeneration delay to account for growth losses in pine.
- Assume 30% growth loss for dead trees based on extrapolating to 60% mortality in Table 1 (fill-plant section)
- Extrapolate from Table 1 to get 40% volume recovery if pine is fill planted; increase to 50% for spruce (more shade tolerant)
- OAF1 becomes 0.60 for the untreated stand, and 0.75 for the treated stand.
- For the treated stand, roughly half of the trees won't be affected by future Dothistroma events, so reduce the regen delay by 2 years to compensate.

Using DFP Survey Data to adjust OAFs for estimating volume losses in stands with a residual overstorey

The DFP (deviation from potential) method of stocking assessment[3] was introduced in 2004 as a means to assess understory stocking levels in stands with a residual overstorey. DFP surveys provide estimates of stocking-related volume loss and overstorey basal-area. DFP data is used with TIPSY's Variable Retention Option to adjust TIPSY OAFs to reflect volume loss in these types of stands.

Compared to a fully stocked stand with no overstorey, a fully stocked stand under an overstorey will produce less volume due to the competitive effects of the overstorey. If the understorey is not fully stocked, there is a further yield penalty. FFT economic analysis typically compare understorey yields for fully stocked (treated-case) versus partially stocked stands (base-case) with the same partial overstorey.

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[3] MoF 2004. A new approach to stocking assessment in stands resulting from MPB salvage partial cutting. Draft Training Session Workbook. Forest Practices Branch, BC Ministry of Forests, Victoria. 46p. http://www.for.gov.bc.ca/hfp/silviculture/MPBI/documents/MPBI_Training_Workbook.pdf

MoF 2005a. The DFP Method of Stocking Assessment. Silviculture Note 30. Forest Practices Branch, BC Ministry of Forest, Victoria. 7p. http://www.for.gov.bc.ca/hfp/silviculture/MPBI/documents/SilvNote30-print.pdf

Martin, Pat, et al. 2005b. A procedure to assess stocking in British Columbia stands partially cut to salvage beetle-infested pine. Forest Practices Branch, BC Ministry of Forests, Victoria. 86p. http://www.for.gov.bc.ca/hfp/silviculture/MPBI/documents/MPBI_Report_Mar_16_05.pdf

STEP 1:   From the DFP survey, compile stratum-level DFP and overstorey basal-area statistics. Ensure the latter includes only live trees, minus those likely to die in the near future (the moribund tree class).

STEP 2:   Generate the treated-case regime:

    a. Begin by entering TIPSY inputs reflecting expectations for a full-stocked understory after treatment (e.g., fill planting).

    b. In TIPSY's Stand Specifications box, tick the Variable Retention (VR) check box and the following box appears:
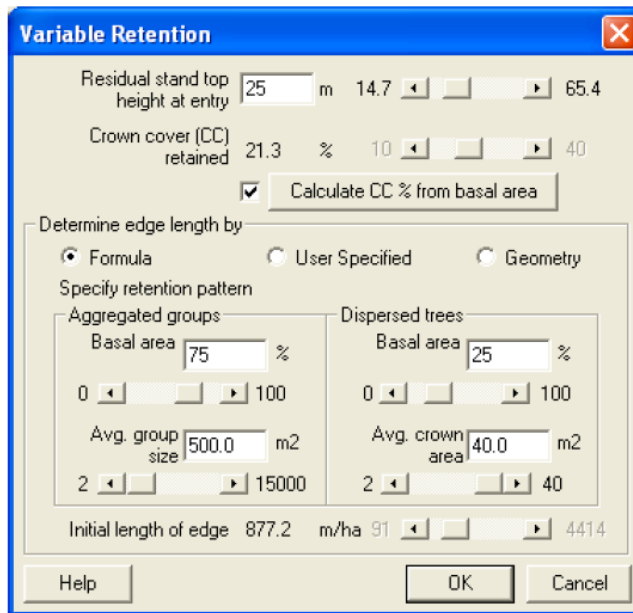
    c. At the top, enter the top height for the residual overstory. If this value was not measured in the field, a reasonable estimate will suffice.

    d. Next, tick the check box beside "Calculate CC% from basal area" and the following secondary box appears:
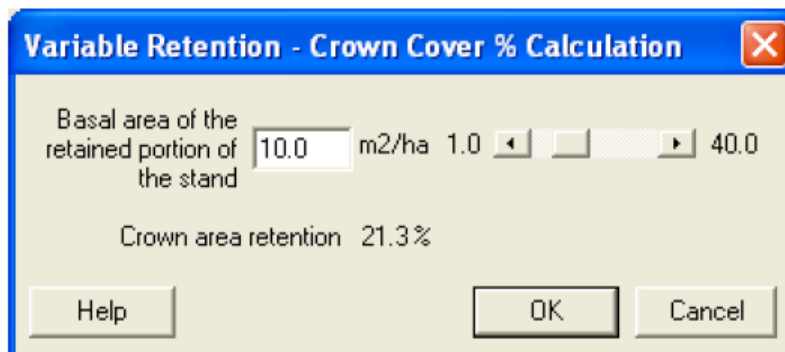
    e. Enter the overstorey basal-area from the DFP survey (STEP 1), then click "OK" to return to the previous box, shown in STEP 2b above.

    f. Ensure that the radio button for "Formula" is selected under the section titled "Determine edge length by".

g. Specify the retention pattern for the overstorey by entering percentage values for aggregated groups (clumps) versus dispersed stems. If unknown, a reasonable distribution is 40% aggregated, 60% dispersed. Then click "OK" to close the VR box. Complete any remaining settings and save the treated-case regime.

Note: TIPSY's VR option does not grow or report overstorey volumes, and the overstorey will not contribute to future harvest volume or value. It also effectively kills all understory trees inside the overstorey's vertical crown shadow. However, it does adjust (reduce) understory growth to reflect overstorey shading along the margins (edge-effect).

STEP 3: Generate the base-case regime:

a. Start by opening the treated-case regime, then use SAVE AS to save and rename it as the base-case regime. Depending on the magnitude of the DFP value from STEP 1, choose one of the following two options to adjust OAF1 to reflect understory volume loss due to natural disturbance.

b. OPTION 1 for low DFP values: calculate the base-case OAF1 as follows:

Base-case OAF1 = (1-DFP) x Treated-case OAF1

If the new base-case OAF1 is greater than 0.5, simply over-write the existing (treated-case) OAF1 and SAVE the regime. Otherwise, TIPSY does not allow OAF1 values less than 0.5 and OPTION 2 is needed.

c. OPTION 2 (items c-h), for high DFP values, involves creating a TIPSY "custom" OAF. Start by ticking the "Custom OAFs" check-box in the Stand Specifications window and the follow box appears (initially without the DFP line):
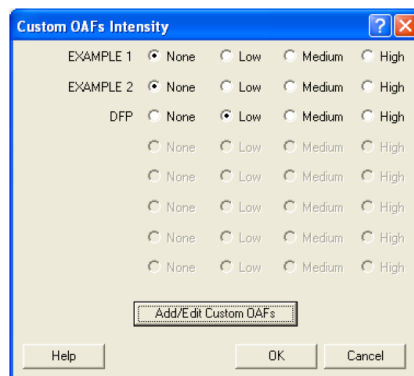

d. Click the "Add/Edit Custom OAFs" button. In the new box that appears (below), click the "Add a new OAF" button, and change the name for the new OAF to "DFP". Near the bottom of the same box, click the "Add" button.
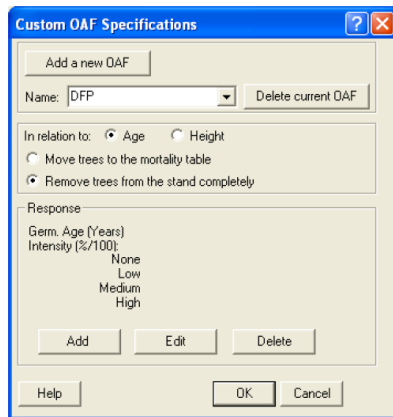
e. In the form that appears (below), enter 100 for the "Germ. Age" (age from germination). In the field beside "Low", enter a value equal to 1-DFP (40 in the example below).
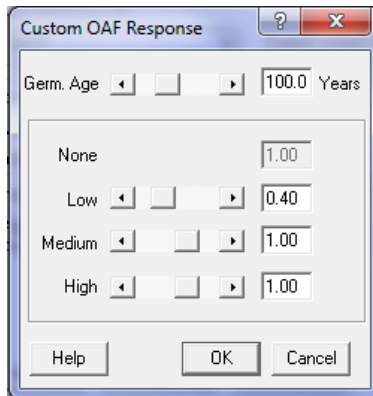
f. Click "OK" to return to the box in "d" above. Click the "Add" button a second time, and repeat step "e", only this time set Germ age = 50 and set "Low" to the same value (1-DFP) again. Click "OK" to return to the previous box again. It should now look similar to the one below.
h. Click "OK" again to return to the main Custom OAFs box, which should now look exactly
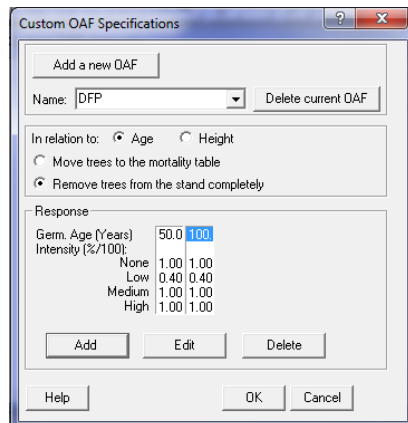
like the one below. Make sure the "Low" is selected on the DFP line, "None" is selected

elsewhere, then click "OK" to return to the Stand Specifications window. Then complete any remaining settings and save the base-case regime.
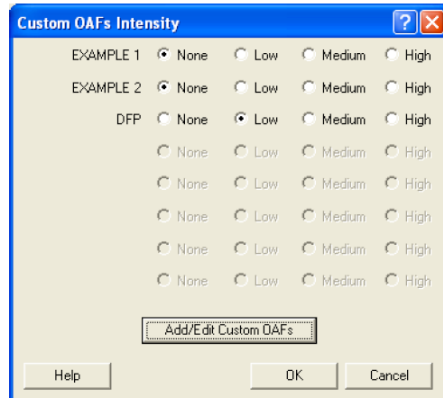
NOTES: In this example, the DFP OAF was arbitrarily assigned to the
            "Low" intensity setting. In this DFP application, the terms low, medium and high
            are meaningless. Users may wish to assign DFP OAFs for neighbouring stand
            strata to the "Medium" and "High" settings as a shortcut to generating additional
            regimes from the same file.

            In this example, the 50 and 100 year points are arbitrary as well. Assigning the
            same OAF value to any two ages creates a "constant" (flat, linear) OAF function
            identical to an OAF1. The Custom OAF feature is used here to generate an OAF
            that behaves like an OAF1, while circumventing TIPSY's 0.50 limit on OAF1.

Appendix A: Video Tutorial Examples

For these demos: TWS = total well-spaced stems/ha using a MITD=2.0m
It can be viewed using TIPSY's Custom Tables feature, where TWS is called
"WS All MITD 2.0+" and total tree density is called "Tree Count 0.0+".

Existing Stand Treatment Demo – Fill Planting, Demo #1

   Base-case: mortality event at age 14
   - SI Region, Chilcotin District, SBPS, 10% slope
   - At stand establishment (no natural disturbance): 100% pine planted at 1600sph, no regen delay, SI=20, default OAFs (0.85, 0.95).
   - With no mortality (OAF1) adjustment, TIPSY predicts 1164 TWS at age 14.
   - At age 14, natural disturbance mortality event leaves behind ~500sph TWS in large size clumps (average diameter = 40m), representing ~57% mortality, i.e., (1164-500)/1164.
   - TIPSY Modelling Strategy[4]: By extrapolation, Table 1 (p21, left side, last row) estimates a yield reduction of ~51% (value C).
     Extrapolation method: 0.45 + (0.45-0.34)/(50-37.5)*(57-50) = 0.51
   - Using Option 2 method (p22): Adjusted OAF1 (base case) = 0.85 * (1 – 0.51) = **0.42** (<0.50, requires Custom OAF)
   - TIPSY with OAF1 adjustment predicts 580sph TWS @14yrs (fairly close to 500 actual).
   - FAN$IER settings (default exceptions):
       o Age at base year = 15 (FFT treatment age)

   Treated-case: fill planting at age 15
   - TIPSY Modelling Strategy[4]: Using Table 1 methods, recalculate OAF1 and apply to base-case settings. By extrapolation, Table 1 (right side) estimates fill planting at age 15 would recover ~78% of the lost volume (value B).
     Extrapolation method: 0.76 + (0.76-0.73)/(50-37.5)*(57-50) = 0.78
   - Using Table 1, Option 2 method (p22):
     Adjusted OAF1 (treated case) = 0.42 * (1 + 0.78*0.51) = **0.59**
   - FAN$IER settings (default exceptions):
       o Age at base year = 15 (FFT treatment age)
       o Other Silviculture Costs (2013$): **$572/ha total**, based on:
           ▪ $32/ha -- Field Assessment / Prescription / ROI / Field Boundary / RESULTS Entry
           ▪ $540/ha -- fill planting 900 trees/ha @ $0.60/tree

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[4] Table 1 is just one of several possible modelling strategies for fill planting; each one has pros and cons. Note Table 1 caveats on p23.

Early Stand Replacement, Demo #2

Base-case: mortality event at age 35
- SI Region, Chilcotin District, SBPS, 10% slope
- Existing stand: 100% pine, SI=20, planted 1200 sph
- At age 35, 65% mortality, ~160 TWS remaining
- Modelling Strategy: clumped, 1200 sph, zero regen delay
    (clumped to better approximate TWS target at 35yrs);
  Adjusted OAF1 = 0.85 * (1 − 0.65) = **0.30**
    (<0.50, requires Custom OAF)
  TIPSY predicts 182 TWS @ age 35 (fairly close to 160 actual).
- FAN$IER settings (default exceptions):
    o Age at base year = 36 (proposed early harvest age)

Treated-case: early harvest and replant vs. stand destruction (knockdown) and replant
- Replacement stand: 100% pine, SI=20, planted 1600 sph , no regen delay,
   default OAFs (0.85, 0.95)
- FAN$IER settings:
    o Age at base year = 0 (default)
    o Early Stand Replacement settings using the "User Specified" option:
      ROI for Special Timber Sale
            Cost and Benefit both = zero (relative to FFT)
      ROI for Stand destruction (knockdown)
            Cost = $1000/ha; Benefit = zero

Appendix B: Other Silviculture Investments

TIPSY and FAN$IER can also be used to analyse other silviculture investments, including some of those funded through the Ministry's Land Base Investment Strategy (LBIS).

Both FFT and LBIS use the same ROI threshold, 2% incremental-IRR. So, FAN$IER's FFT-IRR applies to LBIS, too. The following silviculture treatments are all considered Existing Stand Treatment scenarios, as described earlier in this document (p12). The same basic procedures apply; unique aspects are noted below.

<u>FERTILIZATION</u>

Base case: TIPSY is configured to closely approximate existing stand conditions. Generally, stands being considered for fertilization seldom require forest health adjustments and default OAFs are standard (0.85, 0.95).
In FAN$IER, age at base year = age at fertilization.

Treated case: In TIPSY, modify the base case regime by adding the appropriate fertilization treatment (rate, timing, and efficacy) under Stand Specifications.
In FAN$IER, age at base year = age at fertilization (same as the base case).
Default fertilization costs appear in the Cost Tab under Fertilization. They can be replaced with actual project costs using the User Specified option. Always enter a cost reference year.

NOTE: ROI analyses for LBIS fertilization projects normally use the same rotation length for both base and treated cases. Manually selected the same user-estimated, numerical Harvest Age in FAN$IER for both.

<u>PRE-COMMERCIAL THINNING</u>

At this time, LBIS continues to avoid TIPSY and FAN$IER for pre-commercial thinning (PCT) ROI due to ongoing concerns. I.e., historically, logging and milling cost defaults have not reflected the effects of larger piece sizes. FAN$IER ver1.0 incorporates a new tree-to-truck cost option (FPI Test) that is sensitive to larger piece-size, developed with FPInnovations data. However, LBIS has not evaluated it yet, nor have data been located for developing similar milling cost adjustments. Otherwise, TIPSY and FAN$IER procedures for PCT ROI would be similar to fertilization above, with the possible exception of rotation length definition.

<u>CONIFER RELEASE</u>

TIPSY and FAN$IER do not support conifer release at this time, because TIPSY does not model broadleaf/brush competition.

<u>PRUNING</u>

TIPSY does not support pruning. However, TIPSY's parent model, TASS, and FAN$IER both do. Custom TASS runs can be requested from the Stand Development Modelling Group in Forest Analysis and Inventory Branch. Request FAN$IER-compatible TASS output for ROI analysis.