Stand Rehabilitation Financial Analysis

- Worksheet Documentation -

BC Ministry of Forests

Forest Practices Branch

May 2006

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1.0 Introduction

This document accompanies and supports the "Stand Rehabilitation Financial Analysis" worksheet, a spreadsheet based system for evaluating the financial feasibility of remedial silviculture treatments in young forest stands. This system allows users to quickly assess the costs and benefits of remedial treatments, based on readily available information.

One of the primary intended applications of this system is funding applications under FRPA Section 108, which requires government to grant relief from extra reforestation costs a licensee might experience as the result of certain damaging events. Relief under the act can take the form either of funding to restore the damaged stand to a pre-damage condition, or a reduction in standards so that no further work is required. In applying for relief, a person is required "to provide to the Minister … the nature of the relief sought and why the person is entitled to it" (Forest Planning and Practices Regulation s. 96). In order to distinguish the need for remedial funding as opposed to standards reduction, part of the required process is to provide a financial justification for remedial treatments. This document outlines a set of tools and procedures that can be used to complete such an evaluation.

Financial analysis in the context of this document is a process of evaluating the costs of investment relative to the benefits gained. The costs in this case are the incremental expenditures required to increase productivity through remedial treatment, most typically following a damaging event such as fire or insect attack. The benefits accrue from the increase in future product values that are regained through rehabilitation treatments. The degree to which marginal benefits exceed marginal costs, given an appropriate discount rate for future values, dictates the financial viability of a given project.

Eligible costs are those associated with reaching an acceptable free growing condition after damage has occurred. Since we are interested only in incremental costs, any previously planned treatments required to reach free growing (including the final free growing assessment) would not be considered. Taking this logic one step further, the cost of previously planned treatments that are displaced by new but different treatments would also have to be deducted from the cost of the new treatments. The costs to be included, then, are those in excess of the total regime cost that would have been experienced if the damage had not occurred.

The marginal benefit to be considered is the difference in values between the treated and untreated stands. In order to assign values to these stands, certain assumptions need to be made regarding the biological impacts of damaging agents with regard to timber production, the degree to which remedial treatments will be effective at replacing lost production, and the values associated with future volumes in both the treated and untreated stands. To this end, the methodology here-in relies heavily on values and relationships built into the Ministry of Forests' TIPSY yield model.

While a stand level analysis of costs and benefits has tremendous value, it is important to recognize that other benefits or other methods of evaluating benefits may also be appropriate. Factors that may also be relevant but are not quantified in the analyses presented here include:

- increases in the value of benefits that become apparent using forest estate level rather than stand level evaluations. In management units having future timber supply deficits, benefits of treatments can frequently be realized sooner than assumed in traditional stand level analyses due to shifts in the harvest queue. In such cases, increased future managed stand volumes can decrease the need for rationing natural stands, freeing them up to be harvested at an earlier period. In this way, the increased harvest volumes are realized sooner, and a shorter discount period is required to accurately account for the benefits of treatment.

- benefits that are difficult to quantify, such as visual quality, hydrologic green-up or improved habitat (although in some cases habitat may be optimized by not treating a stand).

In most cases, failure to include factors such as these will result in an under-estimation of treatment benefits. Where such factors exist, they should be explicitly recognized even if not quantified in the financial analysis calculations.

2.0 Application Overview

The procedure for completing a financial analysis on the benefits of stand rehabilitation consists of two major steps. The first of these is the production of yield and financial analysis tables using TIPSY. It is assumed that users are already familiar with this software and can generate the needed yield tables, although some tips on using the model to simulate stand damage and treatment effects are provided in Appendices 1 through 3. Detailed instructions are provided in Section 3.0 for the economic/financial analysis module of TIPSY, as it is critical that model outputs be properly formatted and include the appropriate assumptions.

The second major step involves importing the TIPSY tables into a custom Visual Basic application working within the MS Excel environment, where treated and untreated stands are compared. Based on differentials in operational costs and product values, a set of economic indices are calculated (internal rate of return, net present value and benefit/cost ratios) to help evaluate the financial viability of proposed treatments. Also included in this workbook are options to conduct sensitivity analyses around revenue and cost assumptions.

3.0 Using TIPSY Economist to Produce and Export Financial Analysis Tables

TIPSY Economist is a module within the TIPSY software that supports financial analysis. Within this module are facilities for specifying operational costs (silviculture, road building, harvesting and milling) and product values, and generating financial analysis tables in association with yield tables. As many TIPSY users are far less familiar with this aspect of TIPSY than generating yield tables, a fairly detailed set of instruction for this aspect of the process has been outline below.

Quick Overview:

1. Generate and print TIPSY yield tables for the treated and untreated stands.
2. Ensure the yield tables are generated using 5-year time step
3. For each of the treated and untreated stand yield tables, select the TIPSY Economist option using the  button.

4. Set the Economic Specifications, with particular attention to the Stand Geography section (to get cost and revenue defaults). Do not change cost or lumber value defaults to better match actual values unless you can change all of them.

5. Export the Economic Analysis Tables as **comma delimited** files using the  button. **Do not include Column Headers or Stand Descriptors**.

Detailed Instruction – Step 1

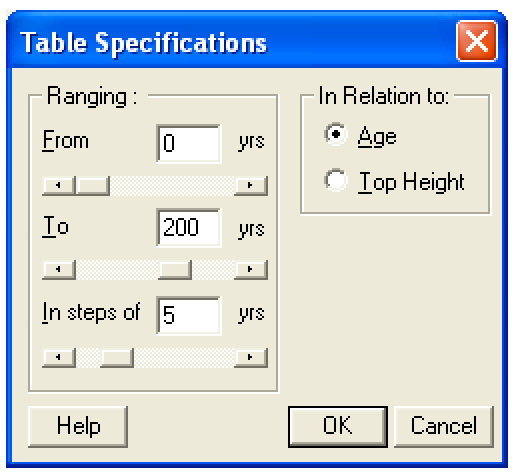
Generate treated and untreated stand TIPSY yield tables for each of the required scenarios.

You must generate a yield table for the untreated stand in all cases, even if it has been completely destroyed. Where no trees remain after disturbance, estimate the number of trees that will regenerate naturally within a reasonable time frame, and include an appropriate regeneration delay in the table specifications.

Select each of the yield tables in turn and complete the following six steps.

Step 2

Ensure that the yield table uses a 5-year time step. If a change is required, go to the **Edit** menu and select Tables (or use the key combination Ctrl-B). Match the entries in the ensuing pop-up window to the following:



Step 3

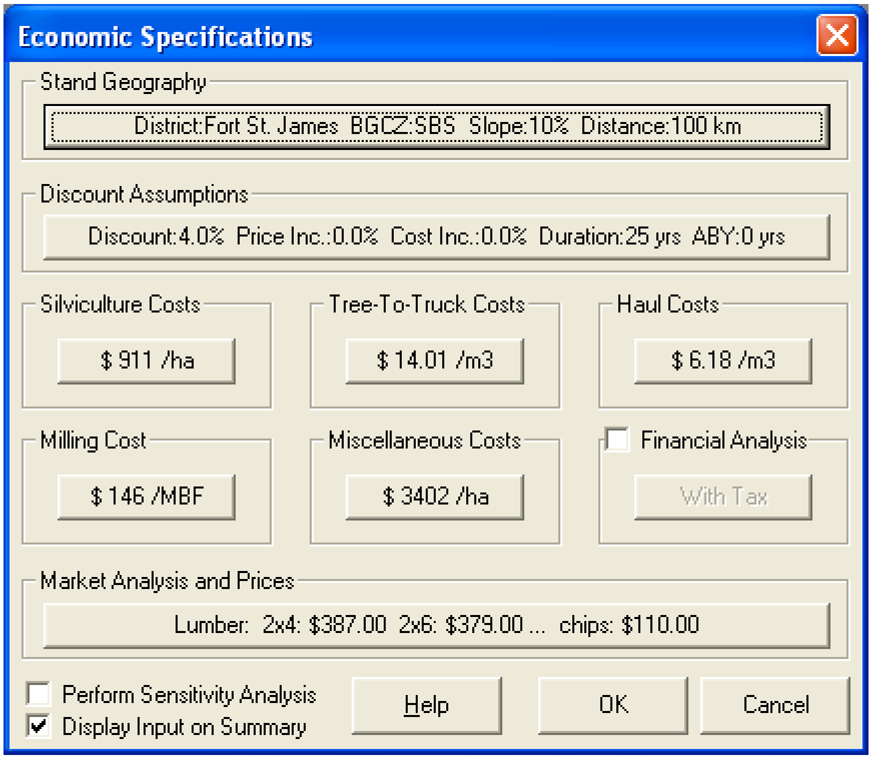
Print each yield table for future reference or to include in reports

Step 4

Initiate the TIPSY Economist routines using the  button.

Step 5

Select the appropriate options on the Economic Specifications form:



Note: the window shown above is from TIPSY version 3.0. In TIPSY versions 3.2 and 4.0, the "Stand Geography" section of this form is replaced by a form which appears when a new run is initiated (the "Project Title and Stand Geography" form). This form can be revisited to adjust inputs by selecting "Title & Geog" under the "Edit" menu.

Each button on this form controls a secondary data entry form. A summary of the entered data is listed on the face of each button.

The only required section of this form is controlled by the **Stand Geography** button (see note below form above if using TIPSY 3.2 or 4.0). Entering the appropriate data here will set location-sensitive defaults for the remainder of the form.

It is best not to make any changes in the **Discount Assumptions**. The discount rate will be varied later in this exercise using a different process, and setting a real price or a real cost increase can lead to erroneous conclusions unless you have very good evidence to suggest such increases will exist.

For the **Costs** and **Prices** sections, default values are based on 1996 dollars (TIPSY 3.0) or 2001 dollars (TIPSY 3.2 and 4.0). Silviculture costs are based on District averages by biogeoclimatic zone, logging/milling costs are based on the appraisal system, and product values are based on long term (1960 to 1996) inflation adjusted averages. Changes can be made to these values, but it ***must*** be an all-or-none approach. Mixing current day values with 1996 default values may seriously skew the analysis. Note that you will be asked to specify, at a later step in the analysis, whether the costs and product values are in current dollars or either 1996 or 2001 dollars.

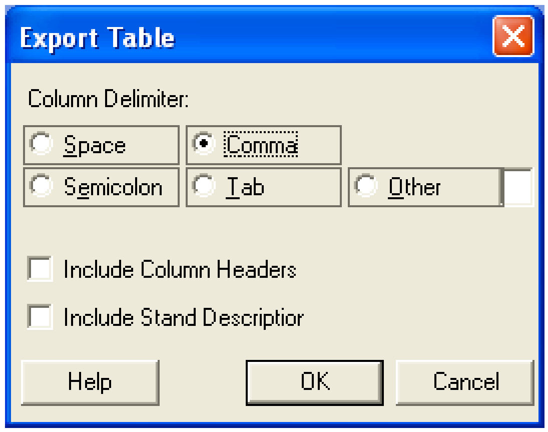
Do not select the **Financial Analysis** or the **Perform Sensitivity Analysis** boxes. Note that sensitivity analysis will be added in at a later stage using a different set of procedures.

Step 6

Print the TIPSY Economist table. You may wish to reference some of the header information at a later stage in the financial analysis.

Step 7

Use the  button to export the TIPSY Economist table. Fill in the **Export Table** form as follows:



You ***must*** select "Comma" as the column delimiter, otherwise your file will not import properly into the Financial Analysis application. Ensure that the Column Headers and Stand Descriptors options remain *unchecked*, as these features will result in an incorrectly formatted file.

In naming your export files, it is best to include a name for the treatment unit and either the word "treated" or "untreated". The best storage location is the same folder as the financial analysis Excel workbook.

4.0 Using the Stand Rehabilitation Financial Analysis Application

The Financial Analysis application is a set of Visual Basic macros embedded in an MS Excel workbook. The application uses a combination of custom code in conjunction with built-in Excel functions to import the desired yield and financial tables from TIPSY, and to calculate the appropriate financial indices. The user is initially presented with an input form containing fields for all of the required user-supplied information. Once this data has been entered, a button labeled "Calculate Financial Indices" will initiate routines to import the TIPSY tables and complete the required calculations. The user is then presented with a partially completed financial analysis form – at this point the only remaining step is for the user to enter information that describes the current (pre-treatment) stand condition and modeling assumptions.

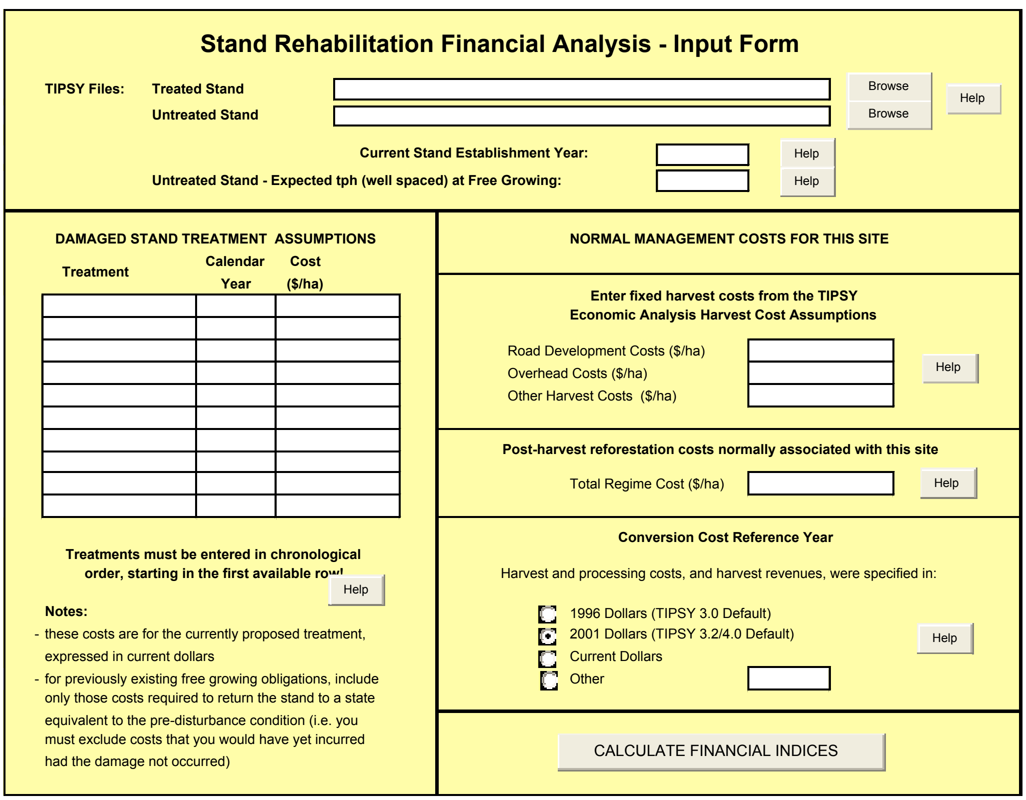
In order to use the Stand Rehabilitation Financial Analysis application, there are a number of steps that must be completed:

Before Getting Started:

1. If this is your first time using the application, create a directory in which to store both the application (IRR Workbook.xls) and your TIPSY yield tables.
2. Collect together the required information on the stand to be analyzed, including:
    - Stocking (trees/ha) by species
    - Site index for the current dominant species (1° species) and the post-treatment dominant species (2° species) if different
    - Stand age
    - Patterns of mortality (patch size distribution)
    - Expected growth impacts resulting from the disturbance (see also Appendices 1 to 3)
    - Expected changes in the stand resulting from treatment (see also Appendices 1 to 3)
3. Complete the required TIPSY runs (treated and untreated stands), and export the TIPSY Economist tables (see Section 3.0).

Once all the base information has been collected and the TIPSY runs completed, the Stand Rehabilitation Financial Analysis application can be initiated, using the following steps.

Step 1: Open the IRR Workbook.xls file. The following form will appear:



Step 2: Specify the location of the TIPSY yield table files, along with information on the current stand:

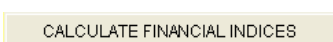
- Use the 'browse' buttons to identify the files representing the untreated and treated yield tables generated in TIPSY
- Estimate the year of establishment for the current stand (use the year by which approximately half of the existing stocking had germinated)
- Estimate the well spaced stocking that will be achieved at free growing assuming no further treatment

Step 3: Specify the expected treatment costs. In this step you will identify all costs required to return the stand to a reasonable approximation of the pre-damage condition (see form below). Costs that must not be included are those that would have still been experienced had the damage not occurred. Note that treatments *must* be entered in chronological order, costs *must* be expressed in current dollars, and treatment descriptions *should not* exceed the allotted space (longer labels will not be adequately displayed on the final report).

Step 4: Estimate development and silviculture costs for future harvests

- Fixed harvest costs (it is possible to use values generated by the TIPSY Economist module)
- Standard post-harvest reforestation costs (it is possible to use values generated by TIPSY)
- Reference year for harvest costs and revenues (i.e. 1996 or 2001 dollars vs. current dollars)

Step 5: Calculate Financial Indices

Select the 

button.

The "Stand Rehabilitation Financial Analysis" form will appear, with completed sections summarizing treated and untreated yield tables (merch volume 12.5+), treatment cost assumptions, harvest cost assumptions and financial indices. Several other sections are provided: one for a user-provided stand description, another to outline modeling assumptions, a third for sensitivity analyses, and (on a second page) two large text fields to describe other affected values and recommended actions.

The top section of this form (worksheet labeled "Main") requires user input to describe the stand. Included in this section are:

Tree Species Expected at Free Growing

Provide a description of the expected stocking (well spaced and total trees/ha) for both the treated and untreated stands, broken down by species.

Clumpiness of Tree Mortality

Provide a percentage breakdown of the clump sizes for mortality (i.e. what percentage of the total mortality falls within each of the clump sizes).

Stand Rehabilitation Financial Analysis

Unit Description: Kenney Dam Fire, Block 1

STAND DESCRIPTION

Damaging Agent: Fire

Tree Species Expected at Free Growing

Spp.	Untreated Total Trees/ha	Untreated w.s Trees/ha	Treated Total Trees/ha	Treated w.s Trees/ha
Pl	500	200	1200	1100

Describe Clumpiness of Tree Mortality (% by Clump Size Class)

Random	0
Small (0 to 5 m)	0
Med. (5.1 to 25 m)	0
Large (> 25 m)	100

1° SI Spp.	Pl
1° SI_{50} (m)	21
2° SI Spp.	
2° SI_{50} (m)	
Stand Age (yrs)	
Top Height (m)	
Mean Height (m)	

Briefly Describe the Modeling Strategy Relative to Stand Damage and Treatment Effects

This stand was almost completely consumed by fire, with minimal residual stocking and low expectations for natural ingress. The treated stand was modeled in TIPSY as a new plantation established at 1400 tph in 2005. The untreated stand was modeled in TIPSY as a clumped stand with an 6 year regen delay and a total stocking of 600 trees/ha. In both cases stands are 100% pine. A value reduction of 40% has been assumed for the untreated stand, to reflect the expected poor fibre quality (high percentage of juvenile wood, coarse branches) of the pine.

YIELD TABLES

Untreated Age	Untreated m^3/ha	Treated Age	Treated m^3/ha
0	0	0	0
5	0	5	0
10	0	10	0
15	0	15	1
20	0	20	15
25	1	25	49
30	11	30	95
35	29	35	142
40	53	40	185
45	78	45	223
50	103	50	257
55	127	55	289
60	151	60	315
65	175	65	336
70	195	70	355
75	213	75	374
80	231	80	391
85	247	85	406
90	262	90	420
95	276	95	432
100	289	100	443

INCREMENTAL TREATMENT COST ASSUMPTIONS

	Calendar Year	Cost ($/ha)
Planting	2005	908
Survey	2007	20

FINANCIAL INDICES (Incremental Costs and Benefits)

	Treated Stand Physical Rotation	Treated Stand Financial Rotation
IRR	5.67%	5.68%
NPV 2%	$5,215	$5,407
NPV 3%	$2,584	$2,695
NPV 4%	$1,141	$1,216
B/C 2%	6.40	6.60
B/C 3%	3.68	3.79
B/C 4%	2.18	2.26

	Untreated	Treated
cMAI	2.9	5.3

HARVEST COST ASSUMPTIONS

	Physical Rotation Untreated	Physical Rotation Treated	Financial Rotation (3%) Untreated	Financial Rotation (3%) Treated
Rotation Age	90	55	70	55
Fixed Harvest Costs ($/ha)	3,852	3,852	3,852	3,852
Tree-To-Truck Costs ($/ha)	3,655	4,023	2,786	4,023
Haul Costs ($/ha)	1,376	1,520	1,026	1,520
Milling Cost ($/ha)	10,062	10,280	7,299	10,280
Harvest Revenue ($/ha)	33,897	32,410	23,822	32,410

SENSITIVITY ANALYSIS

Harvest Revenue	No Change
Conversion Costs	No Change
Treatment Costs	No Change

VALUE ADJUSTMENT FOR STAND DENSITY

Value ratio for untreated stand: 0.6

Damaging Agent

Select the agent that caused the damaging event from the provided drop-down list.

Site Indices, Age and Height

The 1º SI species and 1º SI refer to the dominant species in the untreated stand. The 2º SI species and 2º SI refer to a second species, if different, that is expected to become dominant in the treated stand.

Statistics for stand age, top height and mean height refer to the current stand at the time of reporting.

The second section of this form provides space to describe the modeling strategy. In this space, describe and justify the methodology used to simulate the effects of damage and residual treatments on stand yield. The most important aspect of this section is to provide a clear rationale for the selected modeling options. You will need to be brief, but note that additional space is provided on the second page.

The third section of this form provides a listing of expected yields, treatment and harvest cost assumptions, and financial indices. This data will be the primary criteria by which the financial viability of a particular treatment strategy can be evaluated. Note that all data in this section is automatically entered, and no changes by the user are permitted.

The final section on the first page of this form allows for sensitivity analysis around cost and revenue assumptions. Users can make adjustments of plus/minus 10% or 20% to any of harvest revenues, conversion costs (logging plus milling), or current treatment costs, and observe the changes that occur in the financial indices. Also provided is a method to adjust product values in the untreated stand related to log value reductions associated with stands grown at low densities. This functionality is provided to account for high proportions of juvenile wood and value degrade associated with large knots, severe taper and poor log form that may occur at low stand densities for some species (see also section 4.3).

4.1 Interpreting Financial Indices

Three different financial indices are provided in this analysis methodology. Each of these indices uses essentially the same cost and benefit information, but presents it in a slightly different way. It is also important to note that, properly applied, all of the indices would result in the same positive versus negative result for a particular decision scenario. The indices provided are:

Internal Rate of Return (IRR)

This index is the result of an iterative function that finds the threshold discount rate at which a particular investment scenario is considered to "break even". If the calculated IRR value represents a discount rate that is higher than a threshold acceptable return on investment (interest rate), then the investment is deemed desirable. In comparing investment opportunities, scenarios with the greatest IRR values offer the greatest opportunities for financial gain.

Net Present Value (NPV)

Net Present Value is the difference between the sum of all costs and the sum of all benefits, with all cost and benefit values discounted at a selected interest rate back to the present. In the context of this report, the costs for NPV calculations are those of the remedial treatment, and the benefits accrue from the value differences between the treated and untreated stands. A positive NPV value indicates a positive return on investment, and for a given investment a higher NPV value is better. On its own, however, NPV is inappropriate for ranking investments, as it is insensitive to varying magnitudes of investment that might be required to achieve a given net benefit.

Benefit/Cost Ratios (B/C)

The efficiency of an investment can be derived using a benefit/cost ratio. This index is derived by dividing the discounted revenue stream by the discounted costs. Any investment with a ratio greater than one is deemed attractive, and all investment opportunities can be ranked on an equal footing (higher B/C ratios indicate more efficient use of capital).

For NPV and B/C, index values have been presented using discount rates of 2, 3 and 4%. Over the past few decades a discount rate of 4% has been commonly applied for public forestry investments in BC, but recent thinking on long term investment is leading to use of lower rates. Financial returns on post-harvest reforestation in BC are commonly between 2 and 3%, particularly in the Interior.

It is important to note here that discount rates for forestry investment, particularly on public land, are difficult to compare to other non-forestry opportunities. A major reason for this is that many of the benefits from reforestation are difficult to quantify in monetary terms and are typically ignored. These include but are not restricted to values such as visual quality, habitat, hydrologic management and the satisfaction of carrying out good stewardship. In many cases it is these other values rather than strict financial returns that drive our investment decisions. Where values other than timber will be an atypically large part of the decision process, make sure to note them on page 2 of the form.

4.2 Sensitivity Analysis

A sensitivity analysis section has been provided at the bottom of the Stand Rehabilitation Financial Analysis worksheet to test the impact of assumptions regarding costs and revenues. Using the drop-down lists provided for each of three categories, costs and/or revenues can be scaled upward or downward by 10 or 20%. The resulting changes in financial indices will be immediately calculated and displayed on the worksheet.

The sensitivity analysis section is used to evaluate the degree of certainty an analyst has in the calculated indices, given a range of uncertainty in the input values. This is largely an exercise of exploring “what if my cost or revenue estimates were inaccurate?” By formally varying the inputs by set amounts and observing the results, we can evaluate whether small errors in the inputs have large or small effects on the outputs. If varying an input value within a reasonable range of uncertainty results in the index value exiting the range of acceptable values for a positive investment decision, the investment decision is deemed marginal and should be scrutinized more closely before a final decision is made.

4.3 Value Adjustments for Stand Density

In many cases, stocking reductions resulting from damage events can result not only in volume losses but also in value ($\$/m^3$) losses. In some species (particularly Douglas-fir, lodgepole pine, Sitka spruce and western hemlock[1]), the increase in juvenile wood that results from long live crowns associated with open growing conditions leads to lowered wood strength and dimensional stability. This in turn results in decreased product values.

An allowance has been made to account for this effect in the Stand Rehabilitation Financial Analysis worksheet. Untreated (low density) stands can have their values reduced either by a user defined amount or a default relationship based on species and current stand density. The default relationship is linear, and applies a value multiplier that starts declining at a density equivalent to 80% of the most common target stocking, and drops to a value of 0.4 at 20% of the target stocking. **For all cases where a value change is inappropriate, a multiplier 1.0 should be used.**

5.0 Using the Worksheet for Other Silvicultural Treatments

There are many different silviculture treatments for which financial analysis may be required, some of which are well beyond the intended application of the “Stand Rehabilitation Financial Analysis” worksheet. To the extent that a particular treatment regime has similar benefit assumptions as those used here, however, the spreadsheet may still be applicable. The following factors should be considered before attempting to use the worksheet for other than its originally intended purposes:

1. Benefits accrue primarily from increases in volume, and to a lesser extent from increases in piece size. Piece size premiums are limited to those which result from increased lumber recovery factors overall and to some degree from increased recovery of larger dimension lumber (although the value differentials for 2x10 versus 2x4 lumber in TIPSY are often quite small). There is no consideration of piece size premiums resulting from specialty products.
2. There is no consideration of the effects treatment might have on future conversion costs (i.e. no recognition is given to the reduced future harvest and milling costs that might result from a pre-commercial thinning treatment).

For these reasons, treatments that focus primarily on volume based benefits, such as fill planting, fertilization and afforestation will be well supported by this system. **The worksheet should not be considered for use to support decisions regarding pre-commercial thinning or pruning.**

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[1] Jozsa, L.A. and Middleton, G.R. 1994. A discussion of wood quality attributes and their practical implications. Special Publication SP-34. Forintek Canada Corp., Vancouver. 42 p.

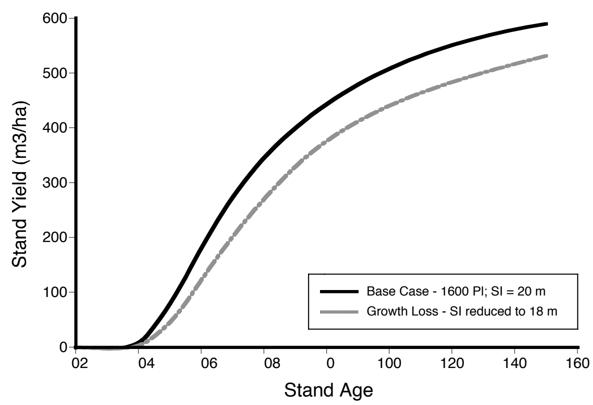
6.0 Concluding Remarks

This document has been prepared to facilitate the process of applying for relief from extraordinary costs related to stand damaging events, where the person applying for funding has an obligation to reach certain reforestation standards. In order to properly use the methods presented here-in, a certain amount of care is required, along with knowledge regarding biological responses to damage and treatment. The system is not a "black box"; persons attempting to use as such will be in serious danger of producing very misleading results.

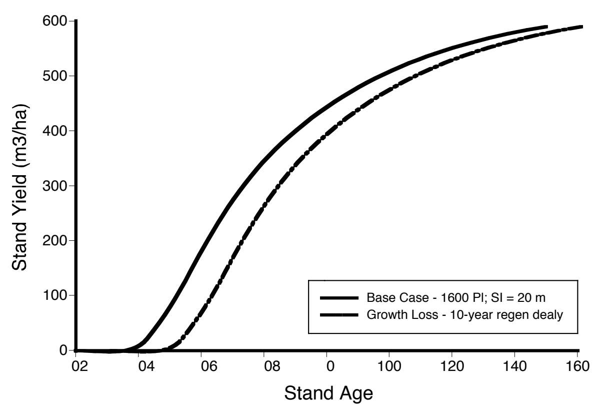
Appendix 1. Using TIPSY to Simulate Yield Impacts of Stand Damaging Agents - A Primer

There are no facilities within TIPSY for simulating the impacts of specific damaging agents. In order for such effects to be included in yield tables, it is necessary to first know something about how a particular agent impacts on stand development, and then estimate the magnitude of that impact. Several user-adjustable features in TIPSY can then be used to include those impacts in the yield tables produced:

> **Site Index**: Where the impact of a damaging agent is a permanent loss of height growth, the effects can be simulated using a reduction in site index. Such cases will be rare.



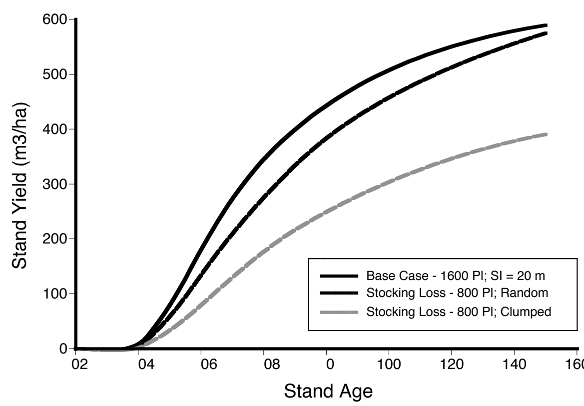
> **Regen Delays**: Where the impact of a damaging agent is a temporary reduction in growth, the impacts can be simulated using a regeneration delay. All of the same stand development milestones are achieved, but at a later date. This methodology has been used in the past to simulate the temporary effects of overtopping competition, and could readily be used to simulate the impacts of defoliators that do not cause mortality.



Stocking Reductions, Spatial Distribution and Stratification: Where the impact of a damaging agent is tree mortality, there are several options depending on the spatial distribution of the killed trees.

For randomly distributed mortality, a simple reduction in trees/ha may be appropriate, possibly coupled with a shift from a "planted" distribution to a "natural" distribution (square spacing versus random spacing). Where the mortality typically occurs in small to medium sized clusters (approximately 10 to 30 trees), the reduction in stocking might be accompanied by a shift to a clumped distribution, although this option is only available for coastal hemlock and interior lodgepole pine. Note, however, that for plantations with patchy mortality, the "clumped" option will likely underestimate yields as the supporting TASS simulations are for tree distributions with tighter clumps and bigger open patches that will normally be the actual case.

For mortality that 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), consideration should be given to 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 as a newly established stand.



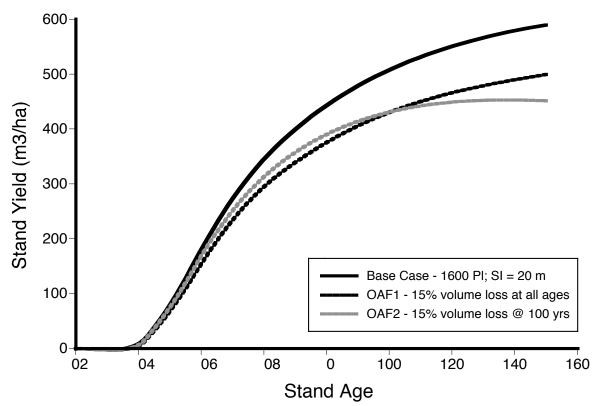
While this methodology can be very effective for simulating the impacts of a disturbance agent on yield, simulating remedial treatments can be problematic. Options for realistically simulating the impacts of fill planting coupled with a stocking reduction are not readily available, but a "work-around" method is provided in Appendix 2.

Operational Adjustment Factors (OAFs):

TIPSY offers two options for adjusting predicted yields using scaling factors. Collectively they are known as Operational Adjustment Factors (OAFs), and are used to adjust the yields of models based on fully stocked, healthy research plots to a level that is expected under average operational conditions.

The first of these (OAF1) is a constant factor (i.e. 0.85 equals a 15% reduction in yield at all ages) that is commonly used to scale predicted yields to account for unstocked gaps, growing space occupied by non-commercial species, small patches of non-productive ground, endemic losses to diseases and other pests, and low level losses to environmental factors such as wind and snow/ice. In the context of this report, an OAF1 might be used to collectively represent the growing space that has been left unoccupied in a plantation resulting from some disturbance agent. An OAF1 will also commonly be used to include user-determined scaling factors for impacts that cannot be simulated in TIPSY using a more biologically realistic approach.

The TIPSY OAF2 is a variable adjustment factor, the impact of which increases with age. The adjustment factor is set by the user at age 100 (i.e. 0.95), and incremented annually at a rate that is 1% of the user defined level (i.e. scaling factor = 1-(1-OAF2)*0.01*age). For an OAF2 of 0.9 then, the scaling factor would be 0.999 at age 1, 0.95 at age 50, 0.9 at age 100, and 0.80 at age 200. In the context of this report, there are likely few applications for an OAF2.



Appendix 2. Using TIPSY to Simulate Yield Impacts of Remedial Treatments

In the context of this document, simulating the impacts of a damaging agent is not sufficient for a thorough analysis. Also required is a comparison to post treatment yield expectations, so that the benefits of treatment can be evaluated. Two general scenarios for including treatment effects in yield tables are described below:

Complete Mortality; Partial Natural Regeneration Expected

In cases where incomplete natural regeneration is expected after a disturbance such as fire, two TIPSY yield tables based on different regeneration expectations will be required:

Run 1: Untreated regeneration scenario using natural regeneration assumptions

Run 2: Treated regeneration scenario using treated stand assumptions (plantation or enhanced natural regeneration)

For the first of these runs, an estimate of the level of natural regeneration expected will be required (trees per hectare by spatial distribution), along with the expected regeneration delay. As the level of natural regeneration will often be difficult to predict, several runs with different levels of natural regeneration may be appropriate (each supporting a separate comparison to the treated stand). In this way, a risk assessment regarding the assumed level of natural regeneration can be completed (i.e. below what level of assumed natural regeneration does the plantation option become financially attractive?).

The second of these runs will represent the treated stand. The descriptive stand parameters used in TIPSY should include the entire expectation for number of trees (planted trees plus natural regeneration contributing to the final crop) along with the appropriate distributional descriptor (the planted stand option should be used even if a significant amount of natural regeneration is expected).

Partial Mortality; Fill Planting is Anticipated

More complex is a situation where only some trees have been killed. In this case, a fill planting regime is required, a set of treatments that are not well supported in TIPSY using any of the standard adjustments. Instead, the impacts of the lost trees must first be determined for the untreated stand, and the remedial effects of fill planting must be estimated (see example in Table 1). The yield impacts of disturbances and treatment can then be applied to the yield curves using OAF1 multipliers.

Table 1. Yield reductions resulting from partial loss of trees in a plantation, 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. For example, 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 14%. Fill planting this stand at age 15 would recover 65% of the lost volume, or 9.1% (0.65 x 0.14) 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 32 m 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	% of trees killed 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
$19.53\ m^2$ (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
$178.57\ m^2$ (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
$1250\ m^2$ (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	% of trees killed 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
$19.53\ m^2$ (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
$178.57\ m^2$ (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
$1250\ m^2$ (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	% of trees killed 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
$19.53\ m^2$ (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
$178.57\ m^2$ (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
$1250\ m^2$ (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	% of trees killed 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
$19.53\ m^2$ (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
$178.57\ m^2$ (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
$1250\ m^2$ (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

To apply values from Table 1 in generating TIPSY yield tables, there are two optional approaches:

Option 1: Use Stocking Reductions in TIPSY to estimated untreated stand yield losses

Under this option, you will generate three TIPSY runs:

Run 1 = yield table with no losses due to disturbance (for initial calculations only – not used in final analysis)

Run 2 = yield table with losses due to disturbance, simulated using stocking reductions and possibly with a spatial deviation

Run 3 = treated stand yield table (Run 2 with adjusted OAF1)

The first step is to calculate the difference in yield at culmination age for the un-impacted and disturbed stands as a proportion of the impacted yield.

A = (Un-impacted MAI – Impacted MAI) / Impacted MAI

The next step is to interpolate a value **(B)** from the right hand side of Table 1 that matches the stand conditions (species x stocking loss x clumpiness x fill plant age) being experienced.

The final step is to calculate the final OAF1 value to be used for the treated stand:

Final OAF1 (Run 3)= Default OAF1 * (1 + A*B)

This new OAF1 value will be applied in place of the OAF1 used in Run2 – note that the adjusted OAF2 will increase the Run 2 yields by a proportion of the volume lost as a result of the disturbance. Note also that the default OAF 1 is the standard OAF1 already used in the un-impacted stand base case, which will typically be 0.85. If no OAF1 was applied to the un-impacted stand, this value will be 1.

Option 2: Use Table 1 to estimated untreated stand yield losses

Under this option, you will generate two TIPSY runs:

Run 1 = yield table with adjusted OAF1 to account for disturbance losses (no other adjustments for stocking losses are required)

Run 2 = yield table with adjusted OAF1 to account for both disturbance losses and fill planting recovery

The first step is to interpolate a value **(C)** from the left hand side of Table 1 that matches the stand conditions (species x stocking loss x clumpiness x disturbance age) being experienced in the disturbed stand. The adjusted OAF 1 for Run 1 then becomes:

Adjusted OAF1 (Run 1) = Default OAF1 * (1 – C)

The second step is to interpolate a value **(D)** from the right hand side of Table 1 that matches the stand conditions (species x stocking loss x clumpiness x fill plant age) being experienced in the treated stand. The adjusted OAF 1 for Run 2 then becomes:

Adjusted OAF1 (Run 2) = Default OAF1 * (1 – C) * (1 + C* D)

As with the first option above, the default OAF1 is the standard OAF1 value used to adjust yields experienced under fully stocked, healthy research plot conditions to those that are typically experienced under operational conditions.

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

- 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 examples.
- 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 square spacing with only minimal latitude (+/- 0.5 m) was assumed in all cases.
- It was always 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.

Aside from adjustments based on values in Table 1, 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
- 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

In all cases where user-defined adjustments are made, there is an even greater importance than normal to perform sensitivity analysis around the assumptions used. Sensitivity analysis can be performed either by completing multiple yield comparisons, or by applying a harvest revenue multiplier in the final analysis (see section 4.2)

Appendix 3. Using TIPSY to Simulate Yield Impacts of Dothistroma Needle Blight – A Case Study

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 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.

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.

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

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, Appendix 2
- Extrapolate from Table 1, Appendix 2 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.

Appendix 4. Overview of Financial Index Calculations

The financial indices calculated for remedial treatments in damaged stands are based on the differences between two sets of cost and revenue streams. An example of such streams might be:

Year	Untreated Stand	Treated Stand
2005		Remedial Treatment Costs ($1160/ha)
2065		Net Harvest Revenue $10,600/ha
2065		Cumulative Value of Future Harvests $730/ha
2085	Net Harvest Revenue $4850/ha	
2085	Cumulative Value of Future Harvests $730/ha	

Where:

Remedial Treatment Costs are specified by the user,

Net Harvest Revenues are calculated as:

NHR = Harvest Revenue - Logging Costs - Haul Costs - Milling Costs - Road Construction Costs - Overhead Costs

Where harvest revenue, logging costs, haul costs and milling costs vary with yield and are derived from TIPSY Economist tables, and fixed road construction and overhead costs are supplied by the user (but may be based on values provided by TIPSY Economist).

Note: where values from TIPSY Economist are provided in 1996 or 2001 dollars, they are inflated to current dollars at a rate of 1 % per annum

Cumulative Value of Future Harvests is based on a discounted stream of reforestation costs and net harvest revenues for an infinite set of future rotations. Typical post-harvest reforestation costs are supplied by the user (but may be taken from values suggested by TIPSY Economist), and rotation lengths and net harvest revenues are based on the rotation length, typical post-harvest reforestation costs and net harvest revenues for the first rotation of the treated stand.

For the calculation of NPV and Benefit/Cost indices, all of the values in the cost and revenue stream are discounted back to the present using the formula:

$$\text{Present Value} = \text{Future Value} / (1 + i)^n$$

Where i is the discount rate and n is the discount period in years.

For the example listed above, discounted costs and revenues (Present Values) assuming a discount rate of 3%, would be:

	Untreated Stand	**Treated Stand**
Remedial Treatment Costs	0	($1160)
Net Harvest Revenue	$456	$1800
Value of Subsequent Harvests	$69	$124

The Net Present Value of the treatment would be calculated as the difference in the discounted revenues, minus the treatment cost:

NPV (3%) = (1800 + 124) – (456 + 69) – 1160

= $239/ha

The Benefit/Cost Ratio of the treatment would be calculated as the difference (increase) in the revenues divided by the treatment cost:

B/C (3%) = ((1800 + 124) – (456 + 69)) / 1160

= 1.21

In order to calculate an Internal Rate of Return (IRR), a single stream of costs and revenues is required (as opposed to the two streams presented above). In order to create a single stream, it is necessary to calculate the differences between the two streams

:

Year	**Treated minus Untreated Cash Flow**
2005	Remedial Treatment Costs ($1160/ha)
2065	Net Harvest Revenue $10,600/ha
2065	Cumulative Value of Future Harvests $730/ha
2085	Forgone Revenue Untreated Stand ($4850/ha)
2085	Forgone Future Harvest Revenues – Untreated Stand ($730/ha)

The built-in Excel function XIRR can then be used to iteratively generate the IRR value for this cash flow as 3.3%.