# REGEN: A SIMULATION MODEL FOR ECONOMIC EVALUATION OF FOREST REGENERATION SYSTEMS

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REPORT O-X-281

CANADIAN FORESTRY SERVICE

DEPARTMENT OF THE ENVIRONMENT

JUNE 1978

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## ABSTRACT

This report describes a computer model developed as a practical decision-making tool to aid forest managers in economic evaluation of alternative regeneration systems. The model employs mainly subjective probability estimates based on the experience of forest managers with various aspects of each regeneration system. Analysis can be based on any one of four economic criteria. The output (simulated results) will indicate the probability that a given regeneration system might be more economical than others. Therefore, the forest manager will be able to choose between regeneration systems with a known degree of confidence. Results of two example runs are described. In one example, the cost-effectiveness of four regeneration systems, i.e., seeding jack pine, planting jack pine, planting white spruce, and planting black spruce, were compared. In the other example, the last three regeneration systems were compared on the basis of internal rate of return. Model sensitivity is discussed briefly. A fully documented program listing of the model and a description of input variables are provided for those wishing to modify the model and/or adapt it to their own computing facilities.



## RÉSUMÉ

Description d'un modèle d'ordinateur préparé en vue de servir de moyen pratique pour aider l'aménagiste forestier à prendre des décisions lors de l'évaluation économique de divers systèmes de régénération. Ce modèle utilise surtout des estimations subjectives de probabilités fondées sur l'expérience des aménagistes forestiers avec divers aspects de chaque système de régénération. On peut fonder l'analyse sur n'importe lequel de quatre critères économiques. Le "rendement" (les résultats simulés) indiquera la probabilité de meilleur résultat économique d'une méthode par rapport aux autres. Par conséquent, l'aménagiste pourra choisir parmi divers systèmes avec un degré connu de confiance. Les auteurs fournissent deux exemples de marches à suivre. Dans le premier, les coût et efficacité de quatre systèmes de régénération (semer du Pin gris, planter du Pin gris, planter de l'Épinette blanche et planter de l'Épinette noire) sont comparés. Dans l'autre, les trois derniers systèmes sont comparés sur la base d'un taux de rendement interne. Suit une discussion brève sur la sensibilité du modèle. Les auteurs ajoutent une énumération pleinement documentée des composantes du modèle et une description des variables d'entrée pour ceux ou celles qui désirent modifier le modèle et/ou l'adapter à leur propre installation d'informatique.

ACKNOWLEDGMENT

The authors would like to thank Dr. T.L. Tucker of the Department of Regional Economic Expansion, Edmonton, Alberta for his contribution in the initial development of the model "REGEN".

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# INTRODUCTION

Artificial regeneration is one of the first and most obvious silvicultural practices marking the beginning of intensive forest management. Unfortunately, most comprehensive and serious efforts to reforest cutover areas are undertaken solely in response to pending wood supply problems. This type of pressure usually focuses efforts on the immediate problems of regenerating both current and backlog cutover areas. Much less attention is paid to the stands that develop from regeneration efforts, their needs for subsequent silvicultural treatment, and the total cost of the wood produced by the various regeneration practices.

As the backlog of unregenerated forest land increases, and as more constraints are placed on silviculture budgets, the need for forest managers to optimize their investment by employing reforestation methods that are both silviculturally and economically efficient becomes increasingly acute. Their task is difficult, however, because, ideally, the silvicultural and economic conditions at stand establishment are related to those at maturity.

While research on the silvicultural aspects of reforestation techniques continues, it is equally important to assess the various systems from an economic standpoint. There are several economic criteria (Payandeh and Tucker 1975) that may be employed for this purpose. In the past few years increasing attention has been paid to the problem of fitting these criteria to a world of uncertainty, where we know that the data base is likely to be in error. This is the case with reforestation, because establishment costs, expected stocking level, physical yield, and future product prices must all be predicted.

One possible solution to this problem is to integrate the probable cost of a reforestation system with its probability of success, and then relate this to the probable yield at a certain price per unit volume. When this has been done for a number of typical reforestation systems, the results can be compared, and the selection of the most efficient system can be based on economic as well as silvicultural considerations.

This type of analysis lends itself very well to simulation modeling. Although simulation cannot provide precise solutions to real problems, it can provide a range of likely outcomes and show tradeoffs between various levels of success and treatment costs. It can also show how feasible a particular reforestation operation is likely to be. The objective of this paper is to describe the final version of a simulation model, developed as a decision-making tool, to aid forest managers in economic evaluation of various forest regeneration systems. The application of the model is demonstrated through detailed description of two example runs. A brief discussion on model sensitivity is also provided along with a program flow chart and a fully documented program listing of the model for those who wish to modify and/or use it on their own computing facilities. The methodology and assumptions employed in developing the model have been discussed elsewhere (Payandeh and Tucker 1975).

## BRIEF DESCRIPTION OF THE MODEL

The model "REGEN" was developed as a practical decision-making tool to aid forest managers in rational economic comparison of various regeneration systems. It may be used to compare the economic desirability of several regeneration systems (including natural regeneration) by one or more of the four economic criteria of: 1) cost-effectiveness, 2) benefit:cost ratio, 3) present net worth, 4) internal rate of return for several species, rotation lengths and interest rates. The model employs mainly subjective estimates provided by the forest manager to generate appropriate probability distributions via the Weibull density function. Each distribution so generated will represent the frequency distribution of a given cost[1], stocking level[2], or future product price for a given reforestation system specified by the forest manager.

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[1] In the simulation process, whenever a regeneration system fails in the initial trial, the area is partially regenerated again and again, up to the number of possible applications/scarifications specified, if necessary, so that it may produce an acceptable stocking level. The cost of partial regeneration treatment as a percentage of the cost of full regeneration is assumed to be a function of percent stocking level from previous regeneration treatments according to equation (1):

$$y = 99.96-87.87(1-e^{-.03255x})^{4.79} \qquad (1)$$

where: $y$ = cost of partial regeneration as a percentage of the cost of complete regeneration

$x$ = percent stocking level from previous regeneration treatments.

[2] The expected additional percent stocking from partial regeneration is assumed to be a function of expected stocking level for initial regeneration and number of years since site preparation or harvest, based on equation (2):

$$y = 0.5\ x_1^{1.1659}\ e^{-.3006x_2} \qquad (2)$$

where: $y$ = expected additional percent stocking from partial regeneration

$x_1$ = expected stocking level from a complete regeneration

$x_2$ = years since site preparation or harvest

The model is constructed so that it simulates all reforestation systems in question in a parallel manner. An area characterized by the input variables is reforested by each regeneration system enough times to produce a desired number, say 250, of successful regeneration treatments. Every stand resulting from a successful reforestation, referred to hereafter as a "success", is then grown to a desired rotation age while all of the costs incurred for stand production (including the cost of unsuccessful treatments) are properly analyzed (compounded or discounted depending on the economic criterion chosen). Finally, a frequency distribution of the final results (future cost per unit volume, benefit:cost ratio, present net worth per unit area, or internal rate of return) for each reforestation system and for the desired number of "successes" is constructed, and from this the results can be obtained for a desired probability interval. Since various reforestation systems are simulated in a parallel manner to produce an equal number of "successes" and the final results are calculated per unit volume or area, the results of each operation are directly comparable. All differences in cost, probabilities of success, stocking levels, regeneration periods, rotation ages, volumes, thinning requirements, future prices, etc., are accounted for. Input estimates may be expressed in either metric or English units. Similarly, the results may be obtained in either one of the two units. Figure 1 shows a program flow chart for the model. A fully documented program listing of the model is given in Appendix I. Description of input variables, an example of input data and an input data blank form for the model are given in Appendix II.

## MODEL APPLICATION: EXAMPLES

### *Input Estimates - Data*

The application of the model, input estimates required and interpretation of the output (results) are demonstrated here by describing two examples in some detail. In the first example, the cost-effectiveness of four regeneration systems was compared: 1) seeding jack pine (*Pinus banksiana* Lamb.), 2) planting jack pine, 3) planting white spruce (*Picea glauca* [Moench] Voss), and 4) planting black spruce (*Picea mariana* [Mill.] B.S.P.). In the second example three regeneration systems were compared on the basis of internal rate of return. These were: 1) planting jack pine, 2) planting white spruce, and 3) planting black spruce. The input estimates used for these examples (see Appendix III) were derived from existing literature (Stiell 1958, Scott 1966, Mullin and Svaton 1972, Mullin and Howard 1973, Waldron 1974, Anon. 1974), or provided by forest managers from the Ontario Ministry of Natural Resources and by other professional foresters. Cost estimates for planting (including stock) and seeding (including seed cost), scarification and thinning for the various regeneration systems compared are assumed to be well within the present

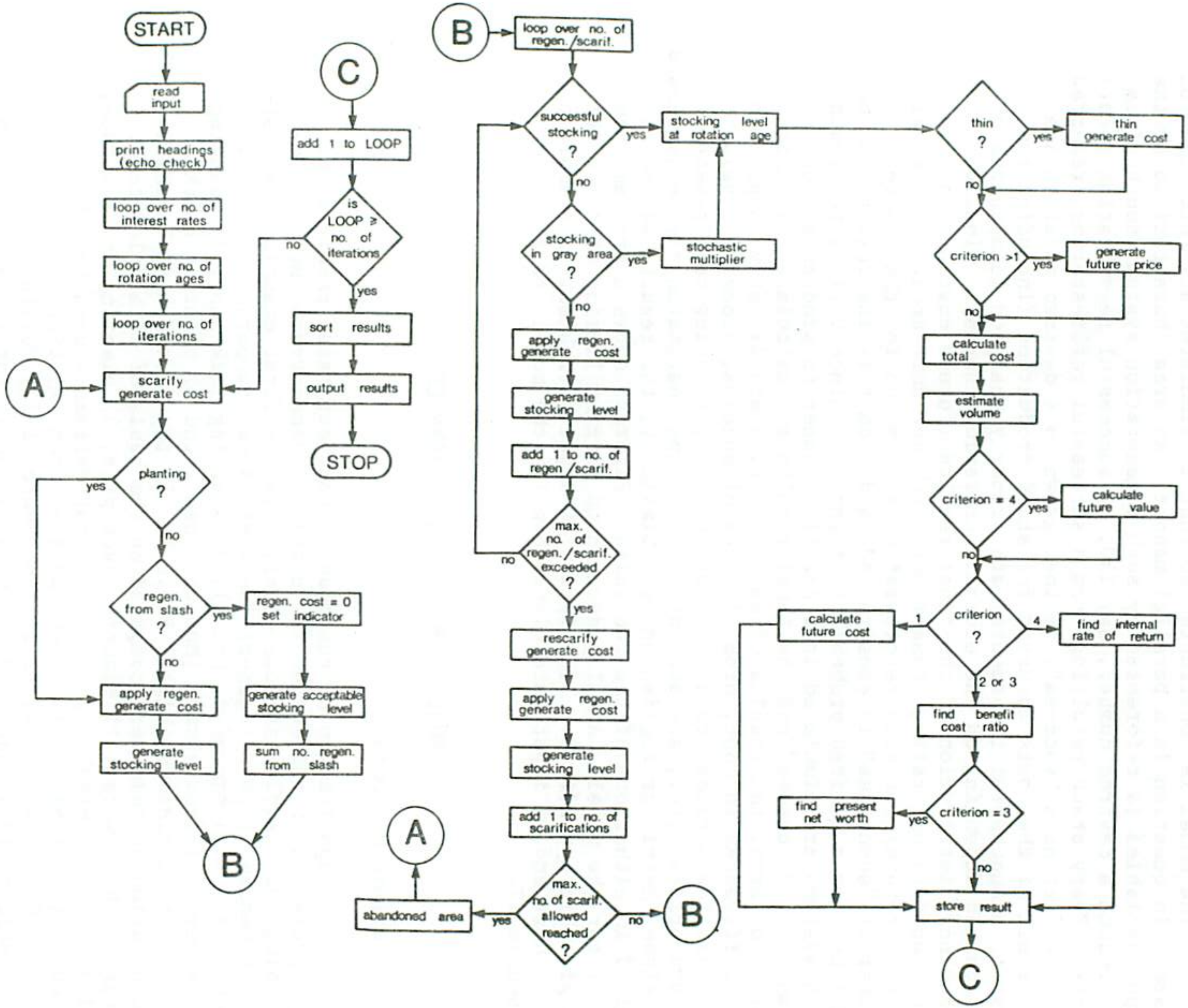


Fig. 1. A program flow chart for simulator "REGEN".

cost structure. Where such estimates were obtained from past data, they were adjusted upwards to represent the recent cost increases. Estimates of stocking level and probability of success for plantations were derived mainly from recent studies by the Ontario Ministry of Natural Resources (Anon. 1974), while estimates for stocking level and probability of success for jack pine seeding were based on estimates provided by seven forest managers from the Ontario Ministry of Natural Resources. Subjective estimates of future price (10 years hence) per unit of volume were approximated from the past stumpage price trends for various species.

Table 1 provides a summary of the input estimates used in the first example. The top portion of this table gives the subjective probability estimates used for costs of seeding or planting, of scarification, and of thinning ($/ha), and the probability of success for each regeneration system. For example, subjective estimates for cost per hectare of seeding jack pine were: a) low estimate = $20.00, b) high estimate = $40.00, c) the probability that cost of seeding jack pine might be lower than the low estimate = .15, d) the probability that cost of seeding jack pine might be lower than the high estimate = .80, and e) the absolute minimum cost of seeding jack pine = $15.00 per hectare. Similarly, the five subjective estimates for the cost of planting jack pine were: $120.00, $200.00, .1, .8, and $65.00 per hectare.

The lower portion of Table 1 gives other input estimates. These included stocking levels for success as 70%, 65%, 70%, and 55% and stocking levels for failure as 40%, 40%, 45%, and 45% for seeding jack pine, planting jack pine, planting white spruce, and planting black spruce, respectively. Different site indices were used for the three species to represent the difference in growth potential of the three species on the same site. Site indices assigned to the four regeneration systems were: 15.00, 18.00, 20.00, and 13.00 (m), respectively. The numbers of additional regeneration treatments per scarification are given as 2, 3, 2, and 3. This means that, in the case of jack pine, for example, an area might be partially reseeded twice, or replanted three times, if necessary, without rescarifying it, before brush competition renders the site unsuitable for additional regeneration treatments. The maximum number of scarifications for the four regeneration systems is 2, 2, 2, and 3, respectively. That is, in the case of the first three regeneration systems, an area might be completely and/or partially reseeded or replanted with one rescarification, and, in the case of planting black spruce, with two rescarifications, if necessary, to produce a successful regeneration before the area is abandoned as a complete failure.

Probabilities of precommercial thinning for the four regeneration methods were 20%, 10%, 5%, and 10%, and the range of ages for

Table 1. Input estimates of simulator "REGEN" for comparing the cost-effectiveness of four regeneration systems: seeding jack pine, planting jack pine, planting white spruce and planting black spruce for rotation ages of 50 and 75 years and interest rates of 9% and 12%

INPUT VARIABLES FOR THIS RUN ARE:

| Subjective estimates | Seeding jack pine | | | | Planting jack pine | | | | Planting white spruce | | | | Planting black spruce | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cost $/ha | | | Stock. | Cost $/ha | | | Stock. | Cost $/ha | | | Stock. | Cost $/ha | | | Stock. |
| | Regen. | Scar. | Thin. | succ. | Regen. | Scar. | Thin. | succ. | Regen. | Scar. | Thin. | succ. | Regen. | Scar. | Thin. | succ. |
| Low | 20.00 | 45.00 | 15.00 | 0.20 | 120.00 | 45.00 | 15.00 | 0.35 | 150.00 | 25.00 | 10.00 | 0.40 | 125.00 | 30.00 | 20.00 | 0.40 |
| High | 40.00 | 85.00 | 50.00 | 0.85 | 200.00 | 70.00 | 40.00 | 0.90 | 250.00 | 60.00 | 30.00 | 0.95 | 225.00 | 60.00 | 35.00 | 0.80 |
| Prob. value less than low | 0.15 | 0.15 | 0.15 | 0.25 | 0.10 | 0.15 | 0.20 | 0.25 | 0.05 | 0.05 | 0.10 | 0.05 | 0.10 | 0.10 | 0.10 | 0.20 |
| Prob. value less than high | 0.80 | 0.80 | 0.80 | 0.85 | 0.80 | 0.80 | 0.80 | 0.85 | 0.95 | 0.80 | 0.80 | 0.90 | 0.80 | 0.90 | 0.90 | 0.70 |
| Absolute minimum | 15.00 | 40.00 | 10.00 | 0.15 | 65.00 | 35.00 | 8.00 | 0.25 | 135.00 | 20.00 | 7.50 | 0.30 | 110.00 | 25.00 | 15.00 | 0.10 |

OTHER INPUT VARIABLES

| | | | | | |
|---|---|---|---|---|---|
| Stocking level for success | 0.70 | | 0.65 | 0.70 | 0.55 |
| Stocking level for failure | 0.40 | | 0.40 | 0.45 | 0.45 |
| Site index | 15.00 | | 18.00 | 20.00 | 13.00 |
| No. possible applications/scarifications | 2 | | 3 | 2 | 3 |
| Max. no. of scarifications | 2 | | 2 | 2 | 3 |
| Prob. stand may be thinned | 0.20 | | 0.10 | 0.05 | 0.10 |
| Low thinning age | 20.00 | | 15.00 | 10.00 | 15.00 |
| High thinning age | 35.00 | | 25.00 | 25.00 | 25.00 |
| Regeneration survey years | 3 | | 2 | 2 | 2 |
| Prob. site may regenerate from slash | 0.15 | | | | |
| Low interest rate (%) | 9 | | 9 | 9 | 9 |
| High interest rate (%) | 12 | | 12 | 12 | 12 |
| Interest rate interval (%) | 3 | | 3 | 3 | 3 |
| No. of iterations | | 250 | | | |
| Starting rotation age | | 50 | | | |
| End rotation age | | 75 | | | |
| Rotation age interval | | 25 | | | |
| Inflation rate | | 0.05 | | | |
| Probability interval for output (%) | | 10.00 | | | |
| Any integer no. 9 digits or less | | 12345 | | | |

thinning was 20-35, 15-25, 10-25, and 15-25 years, respectively. The ages of regeneration survey for the four methods were 3, 2, 2, and 2 years. The probability that an area might be regenerated from slash was set at 15% for seeding jack pine. The low, high and interval for interest rates were 9%, 12%, and 3%, respectively. The number of iterations was set at 250, i.e., the simulation continued until it produced 250 successful regeneration treatments for each regeneration system. The starting, end, and interval for rotation ages were 50, 75, and 25 years. The inflation rate and probability interval for the output were 5%, and 10%, respectively, while the random number for starting the stochastic process was set at 12345.

*Output (Results) and Interpretation*[3]

The first portion of the output for the first example is given in Table 2 and Figure 2. In this example the four regeneration systems were compared on the basis of the cost-effectiveness criterion. With this criterion the regeneration system which produces wood at the lowest future cost per unit volume is considered the most economical method.

Table 2 gives the results for a rotation age of 50 years and an interest rate of 9%. The first portion of this table provides future cost per $m^3$ for the four regeneration systems at 10% probability intervals, while the second portion gives other related statistics per "success". The first column of Table 2, i.e., probability of exceeding, applies to the next 10 columns. The second line, for example, indicates that there is a 10% probability that future cost per $m^3$ will exceed $48.67 for seeding jack pine, $37.39 for planting jack pine, $13.20 for planting white spruce, and $58.05 for planting black spruce, respectively. Conversely, there is a 90% chance that the future cost per $m^3$ will be equal to or less than these figures for the related regeneration systems. Future cost differences for the four regeneration systems are shown in columns 6-11 of the table. These indicate, for example, that there is a 10% chance that the future cost of planting jack pine will be less than that of seeding jack pine by $11.28 per $m^3$, that it will be less than planting black spruce by $20.66, that it will be more than planting white spruce by $24.19, and so on.

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[3] Although the input estimates for examples given here are quite similar to those in Payandeh (1977), the outputs are considerably different, i.e., most future costs are much higher than in the previous report, mainly because the required numbers of reseedings, replantings and rescarifications increased considerably owing to refinement of assumptions regarding the cost and expected additional stocking from partial regenerations.

Table 2. Output of simulator "REGEN" in comparing the cost-effectiveness of four regeneration systems: seeding jack pine, planting jack pine, planting white spruce and planting black spruce for a rotation age of 50 years and an interest rate of 9%.

ROTATION AGE = 50 YEARS, INTEREST RATE = 9%

| Probability of exceeding | Future cost $\$/m^3$ | | | | Future cost difference $\$/m^3$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Seeding jack pine | Planting jack pine | Planting white spruce | Planting black spruce | 1-2 | 1-3 | 1-4 | 2-3 | 2-4 | 3-4 |
| 0.0 | 113.57 | 63.88 | 25.48 | 132.92 | 49.69 | 88.09 | -19.35 | 38.40 | -69.04 | -107.44 |
| 0.10 | 48.67 | 37.39 | 13.20 | 58.05 | 11.28 | 35.46 | - 9.39 | 24.19 | -20.66 | - 44.85 |
| 0.20 | 31.08 | 27.34 | 10.75 | 40.30 | 3.74 | 20.32 | - 9.22 | 16.59 | -12.96 | - 29.54 |
| 0.30 | 23.53 | 21.53 | 9.25 | 32.76 | 2.00 | 14.28 | - 9.23 | 12.28 | -11.23 | - 23.50 |
| 0.40 | 18.80 | 17.66 | 7.97 | 22.36 | 1.14 | 10.83 | - 3.56 | 9.70 | - 4.69 | - 14.39 |
| 0.50 | 15.34 | 14.29 | 6.91 | 16.89 | 1.05 | 8.43 | - 1.55 | 7.38 | - 2.60 | - 9.98 |
| 0.60 | 11.95 | 10.85 | 6.13 | 13.40 | 1.09 | 5.81 | - 1.46 | 4.72 | - 2.55 | - 7.27 |
| 0.70 | 9.00 | 8.73 | 5.50 | 11.21 | 0.27 | 3.50 | - 2.21 | 3.23 | - 2.47 | - 5.71 |
| 0.80 | 6.61 | 6.93 | 5.05 | 9.92 | - 0.32 | 1.55 | - 3.31 | 1.88 | - 2.99 | - 4.87 |
| 0.90 | 4.97 | 5.88 | 4.61 | 8.51 | - 0.91 | 0.35 | - 3.55 | 1.26 | - 2.64 | - 3.90 |
| 1.00 | 2.14 | 3.78 | 3.86 | 7.00 | - 1.63 | - 1.72 | - 4.86 | - 0.09 | - 3.22 | - 3.13 |

RELATED STATISTICS PER SUCCESSFUL REGENERATION ("SUCCESS")

| Statistics | Seeding jack pine | Planting jack pine | Planting white spruce | Planting black spruce |
|---|---|---|---|---|
| Expected volume ($m^3$/ha) | 82.21 | 130.79 | 217.95 | 100.26 |
| Expected present regeneration cost ($/ha) | 92.55 | 233.29 | 207.71 | 313.18 |
| Expected present cost of scarification ($/ha) | 112.05 | 55.99 | 41.20 | 49.51 |
| Total present cost (regen., scarification, thinning) ($/ha) | 205.32 | 289.74 | 248.97 | 363.29 |
| Average stocking (%) | 0.70 | 0.60 | 0.68 | 0.64 |
| Ave. no. of complete and/or partial regen. trials | 3.93 | 1.65 | 1.09 | 2.24 |
| No. of scarifications | 1.98 | 1.04 | 1.00 | 1.22 |
| No. of times stocking in gray area | 0.67 | 0.74 | 0.61 | 0.42 |
| No. of thinnings required | 0.06 | 0.06 | 0.01 | 0.04 |
| No. of times regenerated from slash | 0.14 | 0.00 | 0.00 | 0.00 |
| No. of areas abandoned owing to regen. failures | 0.36 | 0.00 | 0.00 | 0.00 |
| Cost of abandoned areas | 113.34 | 0.00 | 0.00 | 5.68 |
| Expected future cost ($\$/m^3$) | 17.79 | 13.99 | 7.22 | 22.89 |

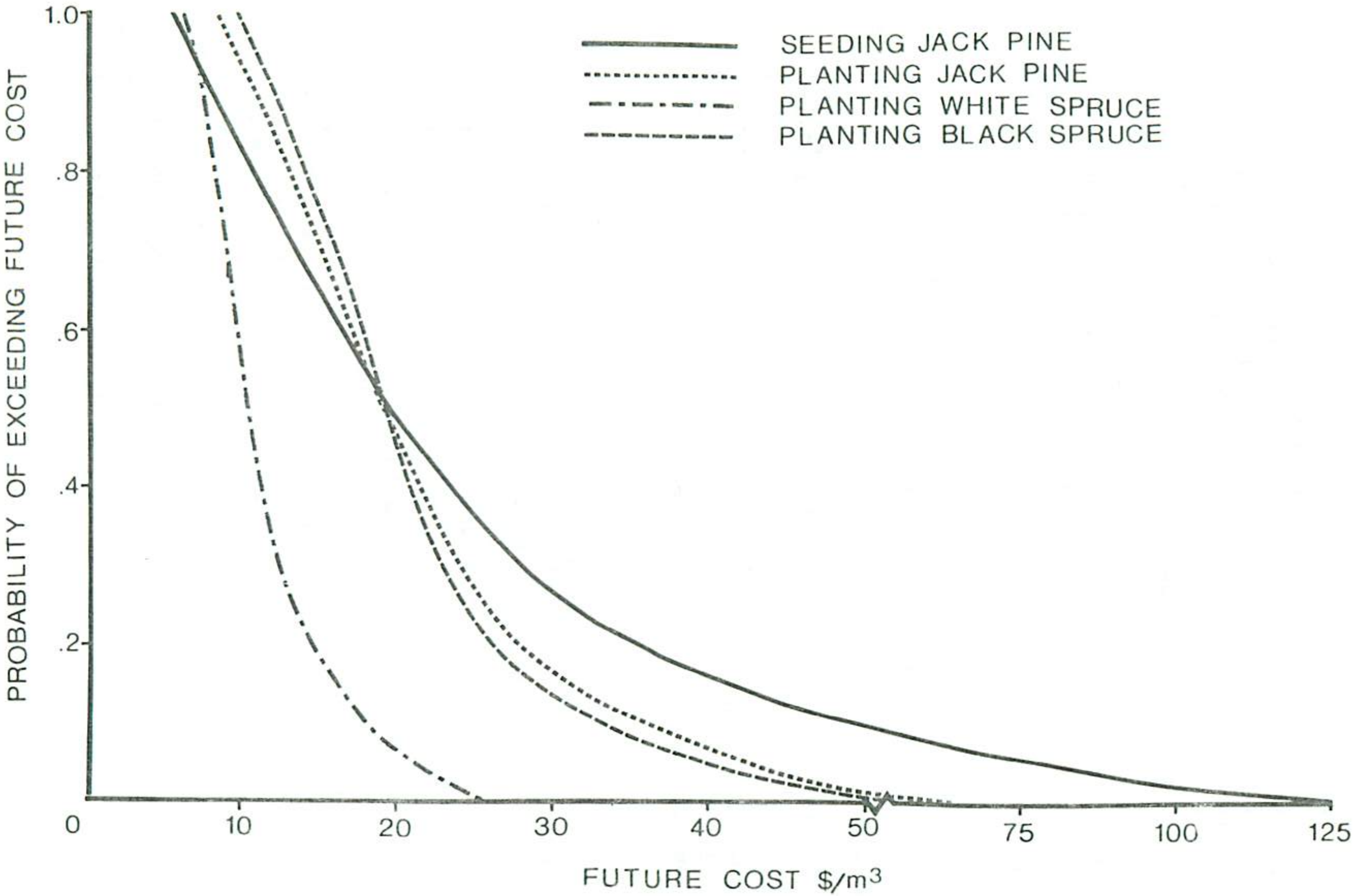


Fig. 2. Probability of exceeding future cost for seeding jack pine, planting jack pine, planting white spruce and planting black spruce at rotation age of 75 years and an interest rate of 9%.

The third line of Table 2 indicates that there is a 20% chance that the future cost per $m^3$ will be between \$31.08 and \$113.57 for seeding jack pine, \$27.34 and \$63.88 for planting jack pine, \$10.75 and \$25.48 for planting white spruce, and \$40.30 and \$132.92 for planting black spruce. Conversely, it indicates that there is an 80% chance that the future cost per $m^3$ of planting white spruce, for example, will be less than that of seeding jack pine, planting jack pine, or planting black spruce by at least \$20.32, \$16.59, and \$29.54, respectively. For the remainder of Table 2, one can make similar comparisons between future cost per $m^3$ for the four regeneration systems at a 10% probability interval. The first and last lines of the table give the maximum and minimum future cost per $m^3$, respectively, for the four regeneration systems compared.

The lower portion of Table 2 provides related statistics per "success" for a rotation age of 50 years and an interest rate of 9%. These include the expected volume for the four regeneration systems: 82.21, 130.79, 217.95 and 100.26 $m^3$ per hectare, respectively. The next three items are the expected present costs per hectare for each of the four regeneration systems. The output indicates that total present costs per hectare were \$205.32 for seeding jack pine, \$289.74 for planting jack pine, \$248.97 for planting white spruce, and \$363.29 for planting black spruce, respectively. Therefore, in terms of total present cost per hectare, on the basis of the input estimates of this example, seeding jack pine will be the cheapest regeneration method and it will be followed by planting white spruce, jack pine and black spruce.

The related statistics provide other useful information as well. For example, they indicate that the average stocking levels per "success" produced for the four regeneration systems were 70%, 60%, 68%, and 64%, respectively. They also indicate that the average numbers of complete and/or partial regeneration treatments per "success" were 3.93, 1.65, 1.09, and 2.24. This means that in the simulation process, on the average, it took 3.93 jack pine seeding and 2.24 black spruce planting trials to produce an acceptable stocking level, while only 65%, and 9% of jack pine and white spruce planting trials, respectively, required additional replanting to produce a "success". The numbers of scarifications per "success" were 1.98, 1.04, 1.00 and 1.22 for the four regeneration systems, respectively. That is, 98% of jack pine seeding, 4% of jack pine planting and 22% of black spruce planting trials required rescarification, while white spruce planting trials did not require rescarification to produce a "success". Results also indicate that 67%, 74%, 61%, and 42% of the time the stocking level fell in the gray area and that 6%, 6%, 1%, and 4% of the stands produced by the four regeneration systems required thinning. Furthermore, in the case of seeding jack pine, 14% of the stands were regenerated from slash, 36% of the areas were abandoned owing to repeated seeding failures, and the cost of such abandoned areas was \$113.34 per hectare. The last line in the related statistics gives the expected future cost per $m^3$ as $17.79 for seeding jack pine, $13.99 for planting jack pine, $7.22 for planting white spruce, and $22.89 for planting black spruce. Thus, for this example, in terms of future cost per $m^3$ volume, planting white spruce will be the cheapest method of reforestation, and will be followed by planting jack pine, seeding jack pine, and planting black spruce.

Since these related statistics are calculated per "success", all differences between the four regeneration systems are considered in terms of initial costs, required additional treatments, i.e., partial and/or complete reseeding or replanting, required thinning and, particularly, expected stocking success. For example, initial subjective estimates for cost per hectare of seeding jack pine were between $20.00 and $40.00 with a minimum of $15.00; however, the expected cost of seeding jack pine per "success" turns out to be $92.55 per hectare. This is simply because, as indicated above, it took 3.93 seeding treatments to produce one "success". Similarly, estimated scarification costs per hectare for seeding jack pine were between $45.00 and $85.00, with a minimum of $40.00. However, the expected cost of scarification per success turns out to be $112.05 per hectare because 98% of the areas had to be rescarified to produce a "success". Differences in thinning requirements, and the possibility that an area might be regenerated from slash in the case of seeding, are also accounted for in the expected total cost per "success".

Results of the above example for a rotation age of 75 years and an interest rate of 9% are plotted in Figure 2. It is noted that the future cost per $m^3$ for all probability levels and therefore the expected future cost for the four regeneration systems are higher than those for a rotation age of 50 years and an interest rate of 9%. This is because the rotation age of 75 years in this example is several years beyond the optimum rotation age. The expected volumes per hectare were, of course, higher for a rotation age of 75 years for all four regeneration systems. Other related statistics for this rotation age were similar to those for the previous rotation age, with some minor differences owing to random chance. The output of this example for rotation ages of 50 and 75 years and an interest rate of 12% were similar to those for an interest rate of 9% except, of course, that all future costs were higher owing to a higher interest rate. These results are therefore omitted here.

As a second example, the economic desirability of three regeneration systems of planting jack pine, white spruce, and black spruce were compared on the basis of internal rate of return. The objective of this comparison is to show that, in addition to costs, differences in future product prices--mainly because of product quality differences--are also considered. With this criterion, the regeneration system that produces the highest internal rate of return will be the most economical method.

The input estimates for the second example were identical to those for the first, with the addition of the following estimates for future prices per $m^3$ 10 years hence: 1) low estimates of \$2.50, \$3.00, and \$2.50 per $m^3$, 2) high estimates of \$3.00, \$3.50, and \$3.00 per $m^3$, and 3) the absolute minimum estimates of \$2.00, \$2.50, and \$2.00 for jack pine, white spruce and black spruce pulpwood, respectively. This example was also run for the two rotation ages of 50 and 75 years.

Results of this example for rotation ages of 50 and 75 years are summarized in Table 3. This table provides the internal rate of return for the three regeneration systems at 20% intervals. For example, it indicates that there is a 20% chance that the internal rate of return will be between 10% and 12% for planting jack pine, between 11% and 13% for planting white spruce and between 9% and 11% for planting black spruce. It also indicates that planting white spruce will be more economical than planting either jack pine or black spruce by 1% to 4%. Results for the 75-year rotation indicate that planting white spruce will be the most economical option while planting jack pine and black spruce will rank about equal.

The results of comparisons between planting jack pine and planting black spruce for both examples remain the same, but in terms of different economic criteria, simply because the same future prices were assumed for both. On the other hand, planting white spruce, when compared with planting jack pine and black spruce, was even more economical in the second example than in the first. This is because future price estimates assumed for white spruce were higher than those for jack pine and black spruce. It is also noted that internal rates of return for planting black spruce were all higher with a rotation age of 75 years than with a rotation age of 50 years. This is because 75 years is closer to optimum rotation for black spruce in this example than is 50 years.

## MODEL SENSITIVITY

Numerous trial runs were conducted to examine the model sensitivity. The results of these trial runs may be summarized as follows:

1) The model is most sensitive to stocking level estimates as related to stocking standards. For example, if stocking standards are lowered by a certain percentage for all regeneration systems, the performance of the regeneration system with lowest expected stocking level shows the most improvement and that with the highest expected level shows the least improvement.

2) The model is quite sensitive to regeneration and scarification cost estimates. That is, if regeneration or scarification costs for all regeneration systems are altered by

Table 3. Output of simulator "REGEN" for comparing the relative economic desirability of three regeneration systems (planting jack pine, planting white spruce and planting black spruce) based on internal rate of return for rotation ages of 50 and 75 years.

| | Internal rate of return | | | | | |
|---|---|---|---|---|---|---|
| | Planting jack pine | | Planting white spruce | | Planting black spruce | |
| | Rotation age | | Rotation age | | Rotation age | |
| Probability of exceeding | 50 | 75 | 50 | 75 | 50 | 75 |
| 0.00 | 0.12 | 0.12 | 0.13 | 0.13 | 0.11 | 0.12 |
| 0.20 | 0.10 | 0.10 | 0.11 | 0.11 | 0.09 | 0.10 |
| 0.40 | 0.09 | 0.09 | 0.11 | 0.11 | 0.08 | 0.09 |
| 0.80 | 0.07 | 0.08 | 0.09 | 0.09 | 0.07 | 0.08 |
| 1.00 | 0.03 | 0.06 | 0.07 | 0.07 | 0.03 | 0.05 |

a certain percentage, the regeneration system with the lowest cost will be most affected. However, if raising the regeneration and/or scarification costs by a fixed amount causes the expected stocking level to rise proportionately for all regeneration systems, the relative economic performance of the regeneration system with the lowest initial cost and/or the lowest expected stocking level will improve the most.

3) Finally, the model is less sensitive to future product price estimates and nearly insensitive to thinning cost estimates.

## CONCLUSION

From the foregoing it should be evident that this type of analysis will provide a practical decision-making tool to aid forest managers in the economic evaluation of various regeneration systems. On the basis of the results of such an analysis, the forest manager may choose the most economical regeneration system for a desired probability level or, alternatively, may select the regeneration system that has the highest probability of meeting objectives such as a minimum future cost per unit volume, a maximum present net worth per unit area, or a maximum rate of return on his investment. He may also choose the regeneration system with the lowest total present cost per unit area.

As stated earlier, although simulation modeling does not provide precise solutions to real problems, it does provide a range of likely outcomes and shows tradeoffs between various levels of costs, prices and probability of success, etc., for different regeneration systems. The application of the model described here has a number of unique features:

1) It capitalizes on the forest manager's experience with various aspects of regeneration systems so as to make a valid comparative economic analysis.

2) The forest manager's opinions expressed as his subjective estimates need not be exact or based entirely on actual data, but the validity of the results produced by the model will be enhanced by realistic estimates. The estimates may be purely subjective, but they must be free of bias.

3) The final results will indicate the probability that one regeneration system might be better than the others and by how much. Therefore, the forest manager may be able to choose a regeneration system knowing the degree of uncertainty involved.

4) If expected present cost per unit area, rather than any of the common economic criteria, is the chosen criterion, the model also provides relevant information on this basis. Therefore, the forest manager may, for example, choose a system for producing the maximum number of successfully regenerated areas with his annual regeneration budget.

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# APPENDICES

# APPENDIX I

## Program listing for simulator "REGEN"

```
C    ***********************************************************************
C    *                                                                     *
C    *  DEFINITION OF VARIABLES                                            *
C    *                                                                     *
C    ***********************************************************************
C
C      INPUT INFORMATION
C      *****************
C
C    * FP - SEE SUBJECTIVE ESTIMATES
C    * ICT - CODE FOR ECONOMIC CRITERION TO BE USED IN ANALYSIS
C                 1 - COST EFFECTIVENESS
C                 2 - BENEFIT COST RATIO
C                 3 - PRESENT NET WORTH
C                 4 - INTERNAL RATE OF RETURN
C    * IK - REGENERATION SURVEY I.E. YEARS AFTER REGENERATION
C    * IND - METHOD OF REGENERATION:  0 - NATURAL; 1 - SEEDING;
C                                      2 - PLANTING.
C      IOUT - OUTPUT OPTION: 1 - SHORT FORM; OTHER THAN 1 - DETAILED.
C      IROT1 - STARTING ROTATION AGE
C      IROT2 - END ROTATION AGE
C      IROT3 - ROTATION AGE INTERVAL
C      IRT1 - LOW INTEREST RATE
C      IRT2 - HIGH INTEREST RATE
C      IRT3 - INTEREST RATE INTERVAL
C      ISP - SPECIES CODE: 1 - BLACK SPRUCE; 2 - JACK PINE;
C                          3 - RED PINE;     4 - WHITE PINE;
C                          5 - WHITE SPRUCE
C      IX - RANDOM NUMBER GENERATOR SEED
C    * MAX - MAXIMUM NUMBER OF SCARIFICATIONS PER REGENERATION TRIAL
C      NIT - NUMBER OF ITERATIONS OF REGENERATION
C      NOM - NUMBER OF ANALYSES FOR EACH SPECIES
C      NOS - NUMBER OF SPECIES INVOLVED IN RUN (MAXIMUM 4)
C    * NS - MAXIMUM # POSSIBLE ADDITIONAL REGENERATION
C           TRIALS/SCARIFICATION
C      PP - PROBABILITY INTERVAL FOR OUTPUT
C    * PSLASH - (OPTIONAL) PROBABILITY SITE WILL REGENERATE FROM SLASH
C      RINF - RATE OF INFLATION
C      RUNID - RUN IDENTIFICATION (ALPHANUMERIC)
C      SI - SITE INDEX
C      SUC1 - SUCCESSFUL STOCKING LEVEL (%) FOR A SPECIES
C      SUC2 - FAILURE STOCKING LEVEL (%) FOR A SPECIES
C      SYSIN - INPUT DATA UNITS CODE: 1 - ENGLISH; 2 - METRIC
C      SYSOUT - OUTPUT DATA UNITS CODE: 1 - ENGLISH; 2 - METRIC
C    * TH - PROBABILITY A REGENERATED STAND WILL BE THINNED
C    * THIN(1,) - LOW THINNING AGE
C          (2,) - HIGH THINNING AGE
C    * TITLE - HEADING FOR EACH SPECIES-REGENERATION METHOD
C
C      SUBJECTIVE ESTIMATES
C      ========== =========
C
C    * FP - FUTURE PRICE (OPTIONAL - FOR ICT=2,3,4)
C    * Y - COST OF REGENERATION
C    * YS - STOCKING LEVEL
C    * YSC - COST OF SCARIFICATION
C    * YTH - COST OF THINNING
C
C       NOTE:  THE ABOVE ARE STORED CONSECUTIVELY Y,YSC,YTH,YS,FP SO AS
C              YSC,YTH,YS AND FP CAN BE REFERENCED AS ELEMENTS OF Y WITH
C              EXTENDED SECOND DIMENSION I.E. Y(5,20)
C
C         (1,)  (2,)   (3,)    (4,)     (5,)
C         LOW   HIGH  PR≤LOW  PR≤HIGH  MINIMUM
C
C    * - INDICATES DIMENSIONED FOR # OF SPECIES-METHOD-CRITERION COMB.
C
C***********************************************************************
C       INTERNAL INFORMATION
C       ********************
C
C       CONV1 - CONVERSION FACTOR (FEET TO METRES)
C       CONV2 - CONVERSION FACTOR (ACRES TO HECTARES)
C       CONV3 - CONVERSION FACTOR (CUNITS TO CUBIC METRES)
C       IM1, IM2, IM3, IM4 - EQUIVALENCED WITH IMTH4
C          - SUBSCRIPT LIMITS OF YS FOR 'INPUT ECHO CHECK' OUTPUT OF FP
C            REFERENCED AS ELEMENTS OF EXTENDED YS FOR 1,2,3 OR 4 ANAL'S
C       DCNT - NUMBER OF COST-EFFECTIVENESS ANALYSES
C       DIND - INDEX OF WHICH ANALYSES ARE COST-EFFECTIVENESS FOR
C              COMPARISON:  (,1) - FIRST ANALYSIS IN COMPARISON
C                           (,2) - SECOND ANALYSIS IN COMPARISON
C       INDX - 1ST SUBSCRIPT INDEX OF ELEMENTS OF Y(5,20) CONVERTED
C       INDY - 2ND SUBSCRIPT BASE INDEX OF ELEMENTS OF Y(5,20) CONVERTED
C       INOM - NUMBER OF ANALYSES FOR A SPECIES
C       INSED - INDEX TO ANALYSES USING SEEDING
C       LIND - NUMBER OF ANALYSES NOT USING INTERNAL RATE OF RETURN (4)
C       M - TOTAL NUMBER OF ANALYSES
C       MINF - SPECIES INFORMATION FOR EACH ANALYSIS (1,) - SPECIES NO.
C              (2,) - SPECIES CODE = ISP
C       NCL - NUMBER OF PERCENTILES IN PROBABILITY TABLE OUTPUT
C       RMINF - STOCKING LEVEL INFORMATION FOR EACH ANALYSIS
C              (1,) - SUCCESSFUL STOCKING LEVEL = SUC1
C              (2,) - FAILURE STOCKING LEVEL = SUC2
C       ROT - CURRENT ROTATION AGE
C       RT - CURRENT INTEREST RATE
C       SLOUT - NUMBER OF ANALYSES USING SEEDING
C
C***********************************************************************
C       VARIABLE FORMAT INFORMATION
C       ***************************
C
C       COMMA - ALPHANUMERIC CONSTANT
C       DIFT - VECTOR OF ALPHANUMERIC COST-EFFECTIVENESS ANALYSIS # PAIRS
C       FRMT01 - VARIABLE FORMAT VECTOR FOR 'INPUT ECHO CHECK' OF PSLASH
C       FRMT02 - VARIABLE FORMAT VECTOR FOR HEADING OF REL. STAT. OUTPUT
C       FRMT03 -    "        "      "     "  VALUES  OF REL. STAT. OUTPUT
C       FRMT04 - VARIABLE FORMAT VECTOR FOR HEADING OF COST DIFFERENCES
C       FRMT05 -    "        "      "     "  VALUES  OF COST DIFFERENCES
C       FRMT91 - VARIABLE FORMAT VECTOR FOR HEADINGS OF SUBJECT. ESTIMATES
C       FRMT92 -    "        "      "     "  VALUES  OF SUBJECT. ESTIMATES
C       FRMT93 - VARIABLE FORMAT VECTOR FOR VALUES OF 'OTHER INPUT VAR.'
C       FRMT94 - VARIABLE FORMAT VECTOR FOR VALUES OF INTEREST RATES
C       FRMT98 - VARIABLE FORMAT VECTOR FOR HEADING OF PROBABILITY TABLE
C       FRMT99 -    "        "      "     "  VALUES  OF PROBABILITY TABLE
C       HEAD1 - ADDITIONAL HEADING VALUE FORMATS FOR FRMT91 (1ST LINE)
C       HEAD2 - ADDITIONAL HEADING FORMATS FOR FRMT91 (2ND LINE)
C       HEAD3 -    "         "       "      "     "   (3RD LINE)
C       HEAD4 - ADDITIONAL SPACING FORMATS FOR FRMT91
```

```
C      HEAD5 - OPTIONAL HEADING FORMATS FOR FRMT91 (2ND LINE)
C      HEAD6 -    "        "       "     "     "   (3RD LINE)
C      HEAD7 - ADDITIONAL VALUE FORMATS FOR FRMT92
C      HEAD8 - OPTIONAL VALUE FORMATS FOR FRMT92
C      IEND - NUMBER OF ADDITIONS TO INITIAL FORMAT FOR 2 ANALYSES
C      IVALU - ADDITIONAL VALUE FORMAT FOR FRMT94
C      LINE - LINE HEADINGS FOR EACH LINE OF SUBJECTIVE ESTIMATES
C      LINES - LINE HEADINGS FOR EACH LINE OF RELATED STATISTICS OUTPUT
C      METLIN - METRIC SUBSTITUTIONS FOR LINE HEADINGS (LINES)
C      METRHD - METRIC SUBSTITUTIONS FOR FRMT91
C      NELTC1 - ARRAY OF POINTERS TO ELEMENTS OF FRMT93 TO ADD COMMAS
C      NELTS1 -    "    "    "    "    "    "    "    "    "  SPACING
C      NELTV1 -    "    "    "    "    "    "    "    "    "  VALUE FMTS
C      NELTV2 - ARRAY OF POINTERS TO ELEMENTS OF FRMT94
C      NUMB - VECTOR OF ALPHANUMERIC NUMBER EQUIVALENTS
C      P - PERCENTILE PROBABILITY POINTS OF PROBABILITY TABLE
C      SPACE - EXTRA SPACING FORMATS FOR FRMT93
C      SUM - ARRAY OF 'RELATED STATISTICS' VALUES FOR EACH ANALYSIS
C      V - ARRAY OF COSTS AND/OR RATES FROM REMETH FOR EACH ANALYSIS
C      VALUE - EXTRA VALUE FORMATS FOR FRMT93 (AND ELSEWHERE)
C
C*************************************************************************
C
      DIMENSION V(100,4),P(100),Y(5,4),YSC(5,4),YTH(5,4),YS(5,4),FP(5,4)
     1,          C(2),SUM(15,4),THIN(2,4),TH(4),SI(4),NS(4),MAX(4),
     2           IK(4),ICT(4),MINF(2,4),ISP(4),SUC1(4),SUC2(4),NOM(4),
     3           D(101,6),RMINF(2,4),PSLASH(4)
      REAL*8 Y,YSC,YTH,YS,FP
      INTEGER TITLE(3,4),IRT(3,4),DCNT,DIND(6,2),IND(4),RUNID(20)
      COMMON NIT,IX,PP,RINF,RT,ROT,I,SYSOUT
      INTEGER FRMT91(114) /'(///',',38X',',''IN','PUT ','VARI','ABLE',
     1        'S FO','R TH','IS R','UN A','RE:''',',/, ',',38X,','33(''',
     2        '-''),',',///,',',24X,','3A4,','12X,','3A4,',','     ','    ',
     3        '    ','    ', '//, ',''' SU','BJEC','TIVE','''',  ',11X,',
     4        '''COS','T $/','ACRE','''4X,',
     5        '''STO','CK.''','    ','    ','    ',',3X,','''COS','T $/'
     6,       'ACRE','''4X,','''STO','CK.''',23*'    ',
     7        '/'' E','STIM','ATES','''',9X',
     8        ',''RE','GEN.',' SCA','R. T','HIN.',' SUC','C.'' ',
     9       3*'    ',',''RE','GEN.',' SCA','R. T','HIN.',' SUC',
     +        'C.'' ', 23*'    ','/ ) ' /
      INTEGER HEAD1(2)/'12X,','3A4,'/,
     1        HEAD2(7)/',3X,',',''COS','T $/','ACRE','''4X,',',''STO',
     2                 'CK.'''/,
     3        HEAD3(7)/',''RE','GEN.',' SCA','R. T','HIN.',' SUC','C.''
     4'/,     HEAD4/'19X,'/, HEAD5(3)/','' F','UTUR','E''  '/,
     5        HEAD6(3)/','' P','RICE',' ''  '/, HEAD7(2)/',4F6',',.2, '/,
     6        HEAD8(2)/',    ','F7.2'/
      INTEGER LINE(6,5)/''' LO','W''',',15X ',3*'    ',
     1                  ''' HI','GH''',',14X ',3*'    ',
     2                  ''' PR','OB. ','VALU','E L ','LOW''',',1X ',
     3                  ''' PR','OB. ','VALU','E L ','HIGH','''    ',
     4                  ''' AB','SOLU','TE M','INIM','UM''',',2X  '/
      INTEGER FRMT92(24) /'(    ',6*'    ','4F6',',.2  ','    ','    ',
     1                 ',4F6',',.2  ',10*'    ',')  '/
      INTEGER IMTH4(4), BLANK/'    '/
      EQUIVALENCE (IMTH4(1),IM1),(IMTH4(2),IM2),(IMTH4(3),IM3),
     +            (IMTH4(4),IM4)
```

```
      INTEGER FRMT93(184) / '(///','50X,',',''OTH','ER I','NPUT',' VAR',
     1         'IABL','ES''',',//, ',''' SP','ECIE','S CO','DE''',',20X,'
     2,'I2, ','22X,','I2, ',4*'    ','/,  ',''' ST','OCKI','NG L','EVEL'
     3,' FOR','''',/,',6X,','''','SUCC','ESS''',',    ','20X,','F4.2',',    '
     4,'20X,','F4.2',6*'    ',',/, ','6X,','''','FAIL','URE''',',20X',
     5',    ','F4.2',',    ','20X,','F4.2',6*'    ',',/, ',''' SI','TE I',
     6'NDEX','''',  ','20X,','F6.2',',    ','18X,','F6.2',6*'    ',',/,'''
     7,' NO.',' POS','SIBL','E AP','PLIC','ATIO','NS''',',',/, ',14X,',
     8'''/SC','ARIF','ICAT','ION''',',5X,','I2, ','22X,','I2, ',4*'    '
     9,'/,  ',''' MA','X. N','O. O','F SC','ARIF','ICAT','IONS','''',  ',
     +'6X, ','I2, ','22X,','I2, ',4*'    ','/,'' ','PROB','. ST','AND ',
     1'MAY ','BE T','HINN','ED''',',6X, ','F4.2',',    ','20X,','F4.2',
     26*'    ',',/, ',''' LO','W TH','INNI','NG A','GE''',',14X,','F6.2'
     3,',    ','18X,','F6.2',6*'    ',',/, ',''' HI','GH T','HINN','ING '
     4,'AGE''',',13X',',F6.','2,  ','18X,','F6.2',6*'    ',',/, ',
     5''' RE','GENE','RATI','ON S','URVE','Y YE','ARS''',',7X,','I2,',
     6'22X,','I2, ',4*'    ','/ )' /
      INTEGER NELTV1(10,2)/19,40,56,72,95,112,130,147,164,181,
     +                     21,43,59,75,97,114,133,150,167,183 /,
     +        NELTS1(10,2)/18,39,55,71,94,111,129,146,163,180,
     +                     20,42,58,74,96,113,132,149,166,182 /,
     +        NELTC1(6,2) /   38,54,70,         128,145,162,
     +                        41,57,73,         131,148,165 /,
     +        NELTV2(3,4) / 8,22,37, 10,24,39, 12,26,41, 14,28,43 /
      INTEGER VALUE(10) /'I2, ',2*'F4.2','F6.2',2*'I2, ','F4.2',2*'F6.2'
     +,                 'I2, ' /,
     +        SPACE(10) /'22X,',2*'20X,','18X,',2*'22X,','20X,',2*'18X,'
     +,                 '22X,' /,
     +        COMMA /',   ' /,
     +        IVALU /'I2, '/
      INTEGER FRMT94(44)/'('' L','OW I','NTER','EST ','RATE',' %''',',
     1        '13X ',',2X,','22X ',',2X,','22X ',',2X,','22X ',',2X,',
     2        '/'' H','IGH ','INTE','REST',' RAT','E %''',',12X',',2X,',
     3        '22X ',',2X,','22X ',',2X,','22X ',',2X,','/'' I','NTER',
     4        'EST ','RATE',' INT','ERVA','L %''',',8X ',',2X,','22X ',
     5        ',2X,','22X ',',2X,','22X ',',2X,','/ ) ' /
      INTEGER FRMT98(23)/'(//,',''' PR','OBAB','ILIT','Y ''',',''' I',
     1                 'CT =',' ''',  ',','  2','(7X,','I1,7','X), ',
     2                 '/,'' ',
     3                 'OF E','XCEE','DING','''',8X',',    ','   2',
     4                 '(2X,','3A4,','1X),','/ ) ' /
      INTEGER FRMT04(19) /'(//2','1X, ','   1','(4X)',',    ',',''FUT',
     1                 'URE ','COST',' DIF','FERE','NCE ','$/CU',
     2                 'NIT''',',//, ','23X,','    ','(2X,','A4,2',
     3                 'X)/)' /
      INTEGER NUMB(6)/'   1','   2','   3','   4','   5','   6' /,
     1        DIFT(6)/'1-2 ','1-3 ','1-4 ','2-3 ','2-4 ','3-4 ' /
      INTEGER FRMT99(10)/'(1X,',' 4X,','F4.2',',4X,','8X, ','   2',
     1                 '(4X,','F8.2',',3X)',')   ' /
      INTEGER FRMT05(5)  /'(21X',',    ','    ','F8.2',')   ' /
      INTEGER LINES(15,13)/'EXPE','CTED',' VOL','UME ','CUNI','TS/A',
     1        'CRE ',8*'    ','EXPE','CTED',' PRE','SENT',' COS','T $/',
     2        'ACRE',8*'    ','EXPE','CTED',' COS','T OF',' SCA','RIFI',
     3        'CATI','ON $','/ACR','E   ',5*'    ','TOTA','L PR','ESEN',
     +        'T CO',
     4        'ST(R','EGEN',',SCA','RIFI','CATI','ON,T','HINN','ING)',
     5        ' $/A','CRE ','    ','AVER','AGE ','STOC','KING',' %  ',
     6        10*'    ','AVG.',' NO.',' OF ','COMP','LETE',' AND','/OR '
     7        'PART','IAL ','REGE','N TR','IALS',3*'    ','NO. ','OF S',
     8        'CARI','FICA','TION','S   ',9*'    ','NO. ','OF T','IMES',
```

```
     9         ' STO','CKIN','G IN',' GRA','Y AR','EA  ',6*'    ','NO. ',
     +         'OF T','HINN','INGS',11*'    ','NO. ','OF T','IMES',' REG'
     1,        'ENER','ATED',' PRO','M SL','ASH ',6*'    ','NO. ','OF A',
     2         'BAND','ONED',' ARE','AS D','UE T','O RE','GEN ','FAIL',
     3         'URES',4*'    ','COST',' OF ','ABAN','DONE','D AR','EAS ',
     4         9*'    ','EXPE','CTED',' FUT','URE ','COST',' $/C','UNIT',
     5         8*'    ' /
      INTEGER FRMT01(24)/'(1X,','''PRO','B. S','ITE ','MAY ','REGE',
     1                   'NERA','TE''/','6X,''','FROM',' SLA','SH'',',
     2                   '17X,','4X  ',',   ','20X,','4X  ',',   ','20X,
     3',                 '4X  ',',   ','20X,','4X  ',')   '/
      INTEGER SLOUT,INSED(4)
      INTEGER FRMT02(10)/'(26X',',''ST','ATIS','TICS','''',25','X,  ',
     1                   '    ','(1X,','3A4,','1X))' /,
     2        FRMT03(8)/'(1X,','15A4',',   ','    ','(4X,','F6.2',
     3                   ',4X)',')   ' /
      INTEGER METRHD(5) /' HA ','CU. ','M / ','HA  ','. M'''/,
     1        SYSIN,SYSOUT,ISYSHD(2)/'NIT)','. M)'/
      INTEGER METLIN(2,4) /'T $/','HA  ','/HA ','    ',' $/H','A   ',
     1                    ' $/C','U. M' /
      INTEGER INDX(3) /1,2,5/, INDY(4)/0,4,8,16/
      REAL CONV1/.3048/, CONV2/.404686/, CONV3/2.83168/
C
C     READ IN GENERAL RUN CONTROL DATA
      READ(5,800) RUNID
  800 FORMAT(20A4)
      READ(5,*) NIT,IROT1,IROT2,IROT3,RINF,PP,IRT1,IRT2,IRT3,IOUT,
     1          SYSIN,SYSOUT
C
C     READ IN # SPECIES AND # ANALYSES
      READ(5,*) NOS,(NOM(I),I=1,NOS)
C     INITIALIZE COUNTERS
      M=0
      LIND=0
C
      IF(NOS.NE.1) GO TO 2
C
C*********************************************************************
C     SINGLE SPECIES RUN
C
C     READ IN SPECIES DATA
      READ(5,*) ISP(1),SUC1(1),SUC2(1)
      INOM=NOM(1)
      M=INOM
      DO 1 I=1,INOM
C     READ IN DATA FOR EACH REGENERATION ECONOMIC ANALYSIS
      READ(5,80) (TITLE(J,I),J=1,3)
   80 FORMAT(3A4)
      READ(5,*) (Y(J,I),J=1,5),(YSC(J,I),J=1,5),
     1          (YTH(J,I),J=1,5),(YS(J,I),J=1,5),SI(I),NS(I),MAX(I),
     2          IK(I),TH(I),(THIN(J,I),J=1,2),IND(I),ICT(I)
C     READ IN OPTIONAL DATA
      IF(IND(I).LE.1) READ(5,*) PSLASH(I)
      IF(ICT(I).NE.1) READ(5,*) (FP(J,I),J=1,5)
C     STORE SPECIES & STOCKING INFORMATION
      MINF(1,I)=1
      MINF(2,I)=ISP(1)
      RMINF(1,I)=SUC1(1)
    1 RMINF(2,I)=SUC2(1)
      GO TO 4
C
C*********************************************************************
C     MULTIPLE SPECIES RUN
C
C     FOR EACH SPECIES
C
    2 DO 3 K=1,NOS
C     READ IN SPECIES DATA
      READ(5,*) ISP(K),SUC1(K),SUC2(K)
      INOM=NOM(K)
C
C     FOR EACH ANALYSIS
      DO 3 I=1,INOM
      M=M+1
C     STORE SPECIES & STOCKING INFORMATION
      MINF(1,M)=K
      MINF(2,M)=ISP(K)
      RMINF(1,M)=SUC1(K)
      RMINF(2,M)=SUC2(K)
C     READ IN DATA FOR REGENERATION ECONOMIC ANALYSIS
      READ(5,80) (TITLE(J,M),J=1,3)
      READ(5,*) (Y(J,M),J=1,5),(YSC(J,M),J=1,5),
     1          (YTH(J,M),J=1,5),(YS(J,M),J=1,5),SI(M),NS(M),MAX(M),
     2          IK(M),TH(M),(THIN(J,M),J=1,2),IND(M),ICT(M)
C     READ IN OPTIONAL DATA
      IF(IND(M).EQ.1) READ(5,*) PSLASH(M)
    3 IF(ICT(M).NE.1) READ(5,*) (FP(J,M),J=1,5)
C
C     PROMPT AND READ IN RANDOM NUMBER GENERATOR SEED
    4 WRITE(6,90)
   90 FORMAT(1H0,10X,'GO TO THE TOP OF THE NEXT PAGE AND TYPE ANY INTEGE
     +R NO. UP TO 9 DIGITS TO START THE SIMULATION',/)
      READ(5,*) IX
C     OUTPUT TITLE
      WRITE(6,909)
  909 FORMAT(1H0,'*****  SIMULATOR REGEN:  A MODEL FOR COMPARING THE REL
     1ATIVE ECONOMIC DESIRABILITY OF  *****',/,1H ,23('*'),'  VARIOUS RE
     2GENERATION TECHNIQUES.  BY B. PAYANDEH & J. FIELD  *****',/)
C     CHECK FOR CONVERSION OF INPUT AND/OR OUTPUT
      IF(SYSIN.EQ.SYSOUT) GO TO 79
      IF(SYSIN.EQ.2) GO TO 77
C     CONVERT INPUT FROM ENGLISH TO METRIC
      DO 76 I=1,M
      SI(I)=SI(I)*CONV1
      DO 76 J=1,4
      DO 76 K=1,3
      IF(J.LT.4) Y(INDX(K),INDY(J)+I)=Y(INDX(K),INDY(J)+I)/CONV2
   76 IF(J.EQ.4) Y(INDX(K),INDY(J)+I)=Y(INDX(K),INDY(J)+I)/CONV3
      GO TO 79
C     CONVERT INPUT FROM METRIC TO ENGLISH
   77 DO 78 I=1,M
      SI(I)=SI(I)/CONV1
      DO 78 J=1,4
      DO 78 K=1,3
      IF(J.LT.4) Y(INDX(K),INDY(J)+I)=Y(INDX(K),INDY(J)+I)*CONV2
   78 IF(J.EQ.4) Y(INDX(K),INDY(J)+I)=Y(INDX(K),INDY(J)+I)*CONV3
C     FIND # OF ANALYSES USING INTERNAL RATE OF RETURN
   79 DO 8 I=1,M
      IF(ICT(I).EQ.4) GO TO 8
      LIND=LIND+1
```

```
    8 CONTINUE
      IF(IOUT.EQ.1) GO TO 200
C
C     DETAILED OUTPUT - INPUT ECHO CHECK
C
      IF(SYSOUT.EQ.1) GO TO 72
C
C     METRIC OUTPUT
C
C     CHANGE HEADINGS TO METRIC
      DO 71 I=1,2
   71 FRMT91(33+(I-1)*10)=METRHD(1)
      HEAD2(4)=METRHD(1)
C     CHECK FOR RUN USING INITIAL SET UP FOR 2 ANALYSES
   72 IF(M.LE.2) GO TO 60
C     MAKE ADDITIONS TO HEADING AND VALUE OUTPUT VARIABLE FORMATS
      IEND=M-2
      DO 6 I=1,IEND
      K=(I-1)*2
      DO 5 J=1,2
      FRMT92(15+2*K+J)=HEAD7(J)
    5 FRMT91(20+K+J)=HEAD1(J)
      K=(I-1)*10
      DO 6 J=1,7
      FRMT91(49+K+J)=HEAD2(J)
    6 FRMT91(93+K+J)=HEAD3(J)
C     FOR EACH ANALYSIS
   60 DO 9 I=1,M
C     SET INDEX TO OUTPUT YS
      IMTH4(I)=I
      IF(ICT(I).EQ.1) GO TO 9
C     FOR OTHER THAN ICT=1 SET INDEX TO ALSO OUTPUT FP
      IMTH4(I)=I+4
      K=9+(I-1)*4
      DO 61 J=1,2
C     MAKE ADDITIONS TO VARIABLE FORMAT FOR VALUE OUTPUT OF FP
   61 FRMT92(K+J)=HEAD8(J)
C     ADD SPACING TO HEADING VARIABLE FORMAT TO CENTER
      IF(I.LT.4) FRMT91(17+2*I)=HEAD4
      K=(I-1)*10
C     ADD HEADING FOR FP IN HEADING VARIABLE FORMAT
      DO 7 J=1,3
      FRMT91(36+K+J)=HEAD5(J)
    7 FRMT91(80+K+J)=HEAD6(J)
    9 CONTINUE
C     PRINT HEADING FOR INPUT ECHO CHECK
      WRITE(6,FRMT91) ((TITLE(J,I),J=1,3),I=1,M)
      DO 11 J=1,5
C     ADD LINE HEADING FOR EACH LINE OF OUTPUT
      DO 10 I=1,6
   10 FRMT92(1+I)=LINE(I,J)
C     PRINT INPUT ECHO CHECK OF SUBJECTIVE ESTIMATES
      IF(M.GT.2) GO TO 100
      WRITE(6,FRMT92) Y(J,1),YSC(J,1),YTH(J,1),(YS(J,I),I=1,IM1,4),
     1                Y(J,2),YSC(J,2),YTH(J,2),(YS(J,I),I=2,IM2,4)
      GO TO 11
  100 IF(M.GT.3) GO TO 101
      WRITE(6,FRMT92) Y(J,1),YSC(J,1),YTH(J,1),(YS(J,I),I=1,IM1,4),
     1                Y(J,2),YSC(J,2),YTH(J,2),(YS(J,I),I=2,IM2,4),
     2                Y(J,3),YSC(J,3),YTH(J,3),(YS(J,I),I=3,IM3,4)
      GO TO 11
  101 WRITE(6,FRMT92) Y(J,1),YSC(J,1),YTH(J,1),(YS(J,I),I=1,IM1,4),
     1                Y(J,2),YSC(J,2),YTH(J,2),(YS(J,I),I=2,IM2,4),
     2                Y(J,3),YSC(J,3),YTH(J,3),(YS(J,I),I=3,IM3,4),
     3                Y(J,4),YSC(J,4),YTH(J,4),(YS(J,I),I=4,IM4,4)
   11 CONTINUE
      IF(M.LT.3) GO TO 14
C     MAKE ADDITIONS TO VARIABLE FORMAT FOR OTHER INPUT VARIABLES
      IEND=M-2
      DO 13 I=1,IEND
      DO 12 J=1,10
      FRMT93(NELTV1(J,I))=VALUE(J)
   12 FRMT93(NELTS1(J,I))=SPACE(J)
      DO 13 J=1,6
   13 FRMT93(NELTC1(J,I))=COMMA
C     PRINT INPUT ECHO CHECK OF OTHER INPUT VARIABLES
   14 WRITE(6,FRMT93) (MINF(2,I),I=1,M),((RMINF(J,I),I=1,M),J=1,2),
     1                (SI(I),I=1,M),(NS(I),I=1,M),(MAX(I),I=1,M),
     2                (TH(I),I=1,M),((THIN(J,I),I=1,M),J=1,2),
     3                (IK(I),I=1,M)
C
      SLOUT=0
      DO 140 I=1,M
      IF(IND(I).GT.1) GO TO 140
C     FOR NATURAL REGENERATION OR SEEDING
      J=(I-1)*3
C     COUNT # ANALYSES
      SLOUT=SLOUT+1
C     SET INDICATOR
      INSED(SLOUT)=I
C     INSERT VALUE FORMATS TO VARIABLE FORMAT FOR PSLASH
      FRMT01(14+J)=VALUE(2)
  140 CONTINUE
C     PRINT PSLASH INPUT ECHO CHECK IF ANY
      IF(SLOUT.NE.0) WRITE(6,FRMT01) (PSLASH(INSED(I)),I=1,SLOUT)
C
      IF(LIND.EQ.0) GO TO 17
      DO 16 I=1,M
      IF(ICT(I).EQ.4) GO TO 16
C     FOR ANALYSES OTHER THAN ICT=4
C     INSERT OUTPUT VALUE FORMATS IN VARIABLE FORMAT FOR INTEREST RATES
      DO 15 J=1,3
   15 FRMT94(NELTV2(J,I))=IVALU
   16 CONTINUE
C     PRINT INTEREST RATE INPUT ECHO CHECK
      WRITE(6,FRMT94) (IRT1,I=1,LIND),(IRT2,I=1,LIND),(IRT3,I=1,LIND)
C     PRINT REMAINING OTHER INPUT VARIABLES OF INPUT ECHO CHECK
   17 WRITE(6,95) NIT,IROT1,IROT2,IROT3,RINF,PP,IX
   95 FORMAT(' NO. OF ITERATIONS',28X,I5,/,
     1                ' STARTING ROTATION AGE',24X,I5,/,' END ROTAT
     2ION AGE',29X,I5,/,' ROTATION AGE INTERVAL',24X,I5,/,' INFLATION RA
     3TE',31X,F5.2,/,' PROBABILITY INTERVAL FOR OUTPUT %',12X,F5.2,/,' A
     4NY INTEGER NO. 9 DIGITS OR LESS',9X,I9,///,45('-'),' ANALYSIS STAR
     5TS HERE ',45('-'),/)
  200 IF(SYSOUT.NE.2) GO TO 198
C     RECONVERT SI TO ENGLISH UNITS IF OUTPUT IS METRIC
      DO 199 I=1,M
  199 SI(I)=SI(I)/CONV1
C
```

```
C     FOR EACH INTEREST RATE
  198 DO 1000 K=IRT1,IRT2,IRT3
      RT=K/100.
C
C     FOR EACH ROTATION AGE
      DO 1000 J=IROT1,IROT2,IROT3
      ROT=J
C
C     FOR EACH ANALYSIS
      DO 18 I=1,M
C     IGNORE LOOP FOR INTEREST RATES FOR INTERNAL RATE OF RETURN ANAL.
      IF(ICT(I).EQ.4 .AND. K.GT.IRT1) GO TO 1000
C
C     ANALYSE
C
      CALL REMETH(V(1,I),P,Y(1,I),YSC(1,I),YTH(1,I),YS(1,I),FP(1,I),
     1            SUM(1,I),NS(I),THIN(1,I),TH(I),SI(I),NCL,IK(I),MAX(I),
     2            RMINF(1,I),RMINF(2,I),ISP(MINF(1,I)),IND(I),
     3            ICT(I),PSLASH(I))
   18 CONTINUE
      IF(K.GT.IRT1 .OR. J.GT.IROT1) GO TO 24
C     PRINT INDEX OF CRITERIA CODES FOR ONLY FIRST ANALYSIS
      WRITE(6,97) ISYSHD(SYSOUT)
   97 FORMAT(//,' ICT = CRITERION  -  ',
     1       /3X,'1 = COST EFFECTIVENESS',5X,'(FUTURE COST $/CU',A4,
     2       /3X,'2 = BENEFIT COST RATIO',/3X,'3 = PRESENT NET WORTH',
     3       /3X,'4 = INTERNAL RATE OF RETURN')
C     PRINT ROTATION AGE AND, IF APPLICABLE, INTEREST RATE
   24 WRITE(6,970) J
  970 FORMAT(//,' ROTATION AGE  =',I4,' YEARS')
      IF(LIND.NE.0) WRITE(6,971) K
  971 FORMAT(' INTEREST RATE =',I4,' %')
C
C     FIND # OF COST-EFFECTIVENESS ANALYSES
      DCNT=0
      IEND=M-1
      DO 19 I=1,IEND
      IF(ICT(I).NE.1) GO TO 19
      IBEG=I+1
      DO 19 L=IBEG,M
      IF(ICT(L).NE.1) GO TO 19
      DCNT=DCNT+1
C     ESTABLISH POINTERS TO COST-EFFECTIVENESS ANALYSES FOR COMPARISON
      DIND(DCNT,1)=I
      DIND(DCNT,2)=L
   19 CONTINUE
      IF(M.LE.2) GO TO 21
      IF(M.EQ.4) GO TO 20
C     FOR 3 ANALYSES
C     ADD REPLICATION FACTOR TO VARIABLE FORMAT FOR HEADING
      FRMT98(9)=NUMB(3)
      FRMT98(19)=NUMB(3)
C     ADD REPLICATION FACTOR TO VARIABLE FORMAT FOR VALUE OUTPUT
      FRMT99(6)=NUMB(3)
      GO TO 21
C     FOR 4 ANALYSES
   20 FRMT98(9)=NUMB(4)
      FRMT98(19)=NUMB(4)
      FRMT99(6)=NUMB(4)
   21 IF(DCNT.EQ.0) GO TO 25
      FRMT04(3)=NUMB(MAX0(1,DCNT-3))
      FRMT04(16)=NUMB(DCNT)
      FRMT05(3)=NUMB(DCNT)
C     PRINT CRITERION FOR EACH ANALYSIS AND HEADING
   25 WRITE(6,FRMT98) (ICT(I),I=1,M),((TITLE(L,I),L=1,3),I=1,M)
      DO 27 N=1,NCL
      IF(DCNT.EQ.0) GO TO 27
C     CALCULATE COST-EFFECTIVENESS COST DIFFERENCES
      DO 26 I=1,DCNT
   26 D(N,I)=V(N,DIND(I,1))-V(N,DIND(I,2))
C     PRINT PROBABILITY TABLE
   27 WRITE(6,FRMT99) P(N),(V(N,I),I=1,M)
C     CHECK FOR COST DIFFERENCE OUTPUT
      IF(DCNT.EQ.0) GO TO 31
C     IF OUTPUT IS METRIC CHANGE COST DIFFERENCE HEADING IN VAR. FORMAT
      IF(SYSOUT.EQ.2) FRMT04(13)=METRHD(5)
C     PRINT COST DIFFERENCE TABLE HEADING
      WRITE(6,FRMT04) (DIFT(MIN0((DIND(I,1)-1)*2,3)+
     1                DIND(I,2)-1),I=1,DCNT)
C     PRINT COST DIFFERENCE TABLE
      DO 28 N=1,NCL
   28 WRITE(6,FRMT05) (D(N,I),I=1,DCNT)
   31 IF(IOUT.EQ.1) GO TO 1000
C
C     DETAILED OUTPUT
C
      FRMT02(7)=NUMB(M)
      FRMT03(4)=NUMB(M)
C     PRINT TITLE
      WRITE(6,900)
  900 FORMAT(///,22X,'RELATED STATISTICS PER SUCCESSFUL REGENERATION',/)
      WRITE(6,FRMT02) ((TITLE(L,I),L=1,3),I=1,M)
      IF(SYSOUT.EQ.1) GO TO 75
C     METRIC OUTPUT
C
C     CHANGE VALUES IN LINE HEADINGS TO METRIC
      DO 73 I=1,3
   73 LINES(4+I,1)=METRHD(1+I)
      DO 74 I=1,2
      LINES(5+I,2)=METLIN(I,1)
      LINES(8+I,3)=METLIN(I,2)
      LINES(12+I,4)=METLIN(I,3)
   74 LINES(5+I,13)=METLIN(I,4)
C     PRINT RELATED STATISTICS
   75 DO 32 I=1,13
   32 WRITE(6,FRMT03) (LINES(L,I),L=1,15),(SUM(I,L),L=1,M)
 1000 CONTINUE
C     PRINT COMPLETION NOTICE
      WRITE(6,902) RUNID
  902 FORMAT(1H ,///,5('.'),' ANALYSIS COMPLETED FOR ',20A4)
   33 STOP
      END
```

```
      SUBROUTINE REMETH(V,P,Y,YSC,YTH,YS,FP,SUM,NS,THIN,TH,SI,NCL,IK,
     1           MAX,SUC1,SUC2,ISP,IND,ICT,PSLASH)
C
C     THIS SUBROUTINE ESTIMATES, ACCORDING TO THE PRESCRIBED ECONOMIC
C     CRITERION, VALUES(COSTS OR RATES), ASSOCIATED PROBABILITIES AND
C     RELATED STATISTICS FROM ITERATIONS OF STOCHASTIC REGENERATION
C     TRIALS.
C
C     VARIABLE DEFINITIONS (IN ORDER OF APPEARANCE)
C     ********************
C
C     V - ESTIMATED COSTS OR RATES
C     P - PROBABILITY LEVELS OF ASSOCIATED PERCENTILE RANKED VALUES OF
C         V
C
C     Y - COST OF REGENERATION SUBJECTIVE ESTIMATES
C     YSC - COST OF SCARIFICATION SUBJECTIVE ESTIMATES
C     YTH - COST OF THINNING SUBJECTIVE ESTIMATES
C     YS - STOCKING LEVEL SUBJECTIVE ESTIMATES
C     FP - FUTURE PRICE SUBJECTIVE ESTIMATES
C     SUM - RELATED STATISTICS
C           (1) - EXPECTED VOLUME
C           (2) - EXPECTED PRESENT COST
C           (3) - EXPECTED COST OF SCARIFICATION
C           (4) - TOTAL PRESENT COST
C           (5) - AVERAGE STOCKING
C           (6) - AVERAGE NUMBER OF COMPLETE AND/OR PARTIAL
C                 REGENERATION TRIALS
C           (7) - AVERAGE NUMBER OF SCARIFICATIONS
C           (8) - AVERAGE NUMBER OF TIMES IN GRAY AREA
C           (9) - AVERAGE NUMBER OF THINNINGS
C          (10) - AVERAGE NUMBER OF TIMES REGENERATED FROM SLASH
C          (11) - AVERAGE NUMBER OF ABANDONNED AREAS DUE TO
C                 REGENERATION FAILURES
C          (12) - AVERAGE COST OF ABANDONNED AREAS
C          (13) - AVERAGE EXPECTED FUTURE COST
C          (14) - AVERAGE PRESENT COST OF THINNING
C     NS - MAXIMUM NUMBER OF POSSIBLE ADDITIONAL
C          REGENERATION TRIALS/SCARIFICATION
C     THIN - LOW (1) AND HIGH (2) THINNING AGE
C     TH - PROBABILITY A REGENERATED STAND WILL BE THINNED
C     SI - SITE INDEX
C     NCL - NUMBER OF PROBABILITY PERCENTILE RANKS
C     IK - REGENERATION SURVEY INTERVAL
C     MAX - MAXIMUM NUMBER OF SCARIFICATIONS
C     SUC1 - SUCCESS STOCKING LEVEL (%)
C     SUC2 - FAILURE STOCKING LEVEL (%)
C     ISP - SPECIES CODE
C     IND - METHOD OF REGENERATION CODE (0-NATURAL 1-SEEDING 2-PLANTING)
C     ICT - ECONOMIC CRITERION CODE
C     PSLASH - PROBABILITY SITE WILL REGENERATE FROM SLASH
C     INDCOM - ALTERNATE STORAGE OF IND FOR PASSING THROUGH COMMON
C     B   - SCALE PARAMETER FOR WEIBULL DISTRIBUTION OF REGENERATION COST
C     C   - SHAPE   "     "     "       "            "
C     BSC - SCALE   "     "     "       "            " SCARIFICATION COST
C     CSC - SHAPE   "     "     "       "            "      "         "
C     BS  - SCALE   "     "     "       "            "   STOCKING LEVEL
C     CS  - SHAPE   "     "     "       "            "      "       "
C     BTH - SCALE   "     "     "       "            "  THINNING COSTS
C     CTH - SHAPE   "     "     "       "            "      "       "
C     BFP - SCALE   "     "     "       "            "   FUTURE PRICES
C     CFP - SHAPE   "     "     "       "            "      "       "
C     RT - RATE OF INTEREST
C     RINF - RATE OF INFLATION
C     STORE - RATE OF RETURN
C     NIT - NUMBER OF ITERATIONS
C     T - CUMULATIVE TOTAL COST OF REGENERATION
C     TSCAR - CUMULATIVE TOTAL COST OF SCARIFICATION
C     K - NUMBER OF SCARIFICATIONS
C     N - NUMBER OF YEARS FROM BEGINNING OF TRIAL
C     ICNT - NUMBER OF COSTS SAVED FOR CALCULATION OF INTERNAL RATE OF
C            RETURN
C     TCOST - TOTAL COST OF SCARIFICATION AND REGENERATION
C     COSTS - VECTOR OF SAVED COSTS FOR CALCULATION OF INTERNAL RATE OF
C             RETURN
C     IYEAR - VECTOR OF YEARS IN WHICH COSTS WERE INCURRED
C     CSCAR - GENERATED COST OF SCARIFICATION
C     IYRPSC - YEAR OF LAST SCARIFICATION
C     RANDU - UNIFORM RANDOM GENERATOR
C     IX - RANDOM NUMBER
C     C1 - GENERATED COST OF REGENERATION
C     IREGSL - INDICATOR FOR REGENERATION FROM SLASH (0-NO; 1-YES)
C     X - GENERATED STOCKING LEVEL AT STAND ESTABLISHMENT
C     IYRS - INTERVAL BETWEEN REGENERATION APPLICATIONS
C     ADDX - ADDITIONAL STOCKING FROM SECONDARY REGENERATION
C     SX - PREVIOUS STOCKING LEVEL
C     CC - COST OF SECONDARY REGENERATION
C     CCAR - COST OF SECONDARY SCARIFICATION
C     C2 - GRAY AREA STOCKING LEVEL STOCHASTIC MULTIPLIER
C     XY - RANDOM VARIATION DUE TO NATURAL REGENERATION
C     RANDN - NORMAL RANDOM NUMBER GENERATOR
C     YY - RANDOM EFFECT(RANDOM ESTIMATE FOR INTERCEPT FOR STOCKING
C          DISTRIBUTION FUNCTION + RANDOM VARIATION)
C     CFA - FINAL STOCKING PER CENT AT ROTATION AGE
C     FPRICE - FUTURE PRICE
C     FC - FUTURE EXPECTED TOTAL COST
C     ROT - ROTATION PERIOD
C     CTHIN - GENERATED COST OF THINNING
C     NTHIN - NUMBER OF THINNINGS
C     VOL - NATURAL STAND VOLUME OF SPECIES AT ROTATION AGE
C     RR - RATIO OF PLANTATION VOLUME/NATURAL STAND VOLUME FOR WHITE
C          SPRUCE
C        - MULTIPLIER FOR ESTIMATING PLANTATION VOLUMES OF SPECIES FROM
C          NATURAL STAND VOLUME
C     XCON - ERROR TERM FOR VOLUME (DIFFERENT FOR PLANTING AND SEEDING)
C     CONV3 - CONVERSION FACTOR (CUNITS/ACRE TO CU. METRES/HECTARE)
C     FUTVAL - FUTURE VALUE
C     ST - VECTOR OF FINAL ESTIMATES (COSTS OR RATES) FOR EACH ITERATION
C     LOOP - NUMBER OF ITERATION
C     DISC - INTERNAL RATE OF RETURN
C     NM - NUMBER OF ANALYSIS
C     PP - PROBABILITY INTERVAL (%)
C     PD - PROBABILITY ASSOCIATED WITH PP
C
      INTEGER SYSOUT
      COMMON NIT,IX,PP,RINF,RT,ROT,NM,SYSOUT
      EXTERNAL RANDU
      DIMENSION ST(5000),P(100),V(100),Y(5),YSC(5),YTH(5),YS(5),SUM(14),
     1          THIN(2),FP(5),COSTS(50),IYEAR(50)
      COMMON/BLK1/ COSTS,IYEAR,ICNT,FUTVAL,INDCOM
      REAL*8 Y,YSC,YTH,YS,FP,B,C,BSC,CSC,BS,CS,BTH,CTH,BFP,CFP
      REAL CONV3/6.99725/
```

```
      INDCOM=IND
      IF(IND.EQ.0) INDCOM=1
C
C     ESTABLISH WEIBULL DISTRIBUTIONS FROM SUBJECTIVE ESTIMATES
      IF(Y(3).NE.0) CALL YPAR(Y(1),Y(2),Y(3),Y(4),Y(5),B,C)
      IF(YSC(3).NE.0) CALL YPAR(YSC(1),YSC(2),YSC(3),YSC(4),YSC(5),BSC,
     +                          CSC)
      CALL YPAR(YS(1),YS(2),YS(3),YS(4),YS(5),BS,CS)
      IF(YTH(3).NE.0) CALL YPAR(YTH(1),YTH(2),YTH(3),YTH(4),YTH(5),BTH,
     +                          CTH)
      IF(ICT.NE.1) CALL YPAR(FP(1),FP(2),FP(3),FP(4),FP(5),BFP,CFP)
C     INITIALIZE RELATED STATISTICS SUMS
      DO 1 I=1,14
    1 SUM(I)=0.0
      STORE=1+RT-RINF
C     FOR EACH ITERATION OF # REQUESTED
      DO 100 LOOP=1,NIT
C     INITIALIZE SUMS AND COUNTERS
      T=0.0
      TSCAR=0.0
   12 K=0
      N=0
      ICNT=0
      TCOST=0.0
C     FIND COST OF SCARIFICATION AND INCREMENT SUM AND COUNTER
      K=K+1
      IYRPSC=0
      IF(YSC(3).EQ.0) GO TO 24
      CSCAR=YBAL(YSC(5),BSC,CSC,RANDU,IX)
      SUM(3)=SUM(3)+CSCAR
      SUM(7)=SUM(7)+1.
      TSCAR=TSCAR+CSCAR
      IF(ICT.NE.4) GO TO 24
C     IF CRITERION IS INTERNAL RATE OF RETURN SAVE COST AND YEAR
      ICNT=ICNT+1
      COSTS(ICNT)=CSCAR
      IYEAR(ICNT)=0
C     CHECK FOR REGENERATION FROM SLASH
   24 IREGSL=0
      IF(IND.LE.1 .AND. RANDU(IX).LT.PSLASH .AND. K.LE.MAX) GO TO 130
      IF(Y(3).EQ.0) GO TO 13
C     FIND COST OF REGENERATION
      C1=YBAL(Y(5),B,C,RANDU,IX)
      IF(ICT.NE.4) GO TO 23
C     IF CRITERION IS INTERNAL RATE OF RETURN SAVE COST AND YEAR
      ICNT=ICNT+1
      COSTS(ICNT)=C1
      IYEAR(ICNT)=0
C     INCREMENT SUMS AND COUNTER FOR REGENERATION
   23 SUM(2)=SUM(2)+C1
      SUM(6)=SUM(6)+1.
      T=T+C1
      GO TO 21
  130 IREGSL=1
   13 C1=0.0
C     FIND STOCKING LEVEL
   21 X=YBAL(YS(5),BS,CS,RANDU,IX)
      IF(IREGSL.EQ.1) X=YBAL(SUC2,BS,CS,RANDU,IX)
C     INCREMENT COUNTER FOR REGENERATION FROM SLASH
      IF(IREGSL.EQ.1) SUM(10)=SUM(10)+1.
      IYRS=IK
      IF(IND.EQ.0) IYRS=1
C     SAVE STOCKING LEVEL
    2 SX=X
      ADDX=0
      IF(NS.EQ.0) GO TO 50
C     FOR EACH REGENERATION APPLICATION UP TO MAXIMUM ALLOWED
      DO 5 M=1,NS
      IF(X.GT.SUC1) GO TO 9
      IF(X.GT.SUC2) GO TO 3
C
C     STOCKING FAILURE
C
C     APPLY REGENERATION AGAIN
      N=N+IYRS
C     FIND REVISED STOCKING LEVEL
      ADDX=0.5*(SX*100)**1.1659*EXP(-.3006*(N-IYRPSC))/100.*(1-SX)+ADDX
      X=SX+ADDX
      IF(Y(3).EQ.0) GO TO 5
C     FIND COST OF SECONDARY REGENERATION
      CC=(99.96-87.87*(1-EXP(-.03255*SX*100.))**4.79)/100.*C1
      IF(ICT.NE.4) GO TO 22
C     IF CRITERION IS INTERNAL RATE OF RETURN SAVE COST AND YEAR
      ICNT=ICNT+1
      COSTS(ICNT)=CC
      IYEAR(ICNT)=N
C     FIND COST DISCOUNTED TO PRESENT AND INCREMENT SUMS AND COUNTER
   22 CC=CC/STORE**N
      SUM(2)=SUM(2)+CC
      SUM(6)=SUM(6)+1.
      T=T+CC
    5 CONTINUE
C
C     RESCARIFY
C
C     UPDATE COUNTER
   50 K=K+1
      IF(K .GT. MAX) GO TO 11
      IF(YSC(3).EQ.0) GO TO 57
C     UPDATE YEAR AND FIND COST OF RESCARIFYING
      IYRPSC=N
      CCAR=YBAL(YSC(5),BSC,CSC,RANDU,IX)
      IF(ICT.NE.4) GO TO 55
C     IF CRITERION IS INTERNAL RATE OF RETURN SAVE COST AND YEAR
      ICNT=ICNT+1
      COSTS(ICNT)=CCAR
      IYEAR(ICNT)=N
C     FIND COST DISCOUNTED TO PRESENT AND INCREMENT SUMS AND COUNTER
   55 CCAR=CCAR/STORE**N
      SUM(3)=SUM(3)+CCAR
      SUM(7)=SUM(7)+1.
      TSCAR=TSCAR+CCAR
C     FIND STOCKING LEVEL AND COST OF REGENERATION
   57 X=YBAL(YS(5),BS,CS,RANDU,IX)
      IF(Y(3).EQ.0) GO TO 2
      CC=YBAL(Y(5),B,C,RANDU,IX)
      IF(ICT.NE.4) GO TO 56
C     IF CRITERION IS INTERNAL RATE OF RETURN SAVE COST AND YEAR
      ICNT=ICNT+1
      COSTS(ICNT)=CC
```

```
      IYEAR(ICNT)=N
C     FIND COST DISCOUNTED TO PRESENT AND INCREMENT SUMS AND COUNTER
   56 CC=CC/STORE**N
      SUM(2)=SUM(2)+CC
      SUM(6)=SUM(6)+1.
      T=T+CC
      GO TO 2
C
C     REGENERATION FAILURE
   11 SUM(11)=SUM(11)+1.
      SUM(12)=SUM(12)+T+TSCAR
      GO TO 12
C
C     STOCKING LEVEL IN GRAY AREA
    3 C2=(RANDU(IX)*(1-X)+X)
      SUM(8)=SUM(8)+1.
      GO TO 6
C
C     STOCKING LEVEL SUCCESS
C
    9 C2=1
C     ESTABLISH ERROR BAND PARAMETERS FOR FINAL STOCKING LEVEL
    6 XY=SIN(X*3.14159)*RANDN(IX,RANDU)
      IF(IND.LE.1) XY=XY*.05
      IF(IND.EQ.2) XY=XY*.03
      SUM(5)=SUM(5)+X
      YY=(RANDU(IX)*10+8.54)+2*RANDN(IX,RANDU)
C     FIND FINAL STOCKING LEVEL
      CFA=(((YY+(104-YY)*(1-EXP(-.058851*(X*100)))**10.122)/100)+XY)*C2
      IF(CFA.GT. 0.85 .AND. RANDU(IX).LT. TH) GO TO 7
C
C     NO THINNING
C     INCREMENT SUMS TO FINAL TOTALS
      TCOST=TCOST+T+TSCAR
      SUM(4)=SUM(4)+TCOST
C     IF REQUIRED FIND FUTURE PRICE
      IF(ICT.NE.1) FPRICE=YBAL(FP(5),BFP,CFP,RANDU,IX)
C     FIND FUTURE EXPECTED TOTAL COST AND INCREMENT SUM
      FC=(T+TSCAR)*STORE**(ROT-3*(INDCOM-1))
      SUM(13)=SUM(13)+FC
      GO TO 8
C
C     THINNING
C
C     FIND COST OF THINNING AND YEAR THINNED
    7 CTHIN=YBAL(YTH(5),BTH,CTH,RANDU,IX)
      NTHIN=RANDU(IX)*(THIN(2)-THIN(1))+THIN(1)
      IF(ICT.NE.4) GO TO 77
C     IF CRITERION IS INTERNAL RATE OF RETURN SAVE COST AND YEAR
      ICNT=ICNT+1
      COSTS(ICNT)=CTHIN
      IYEAR(ICNT)=NTHIN
C     FIND COST DISCOUNTED TO PRESENT AND INCREMENT SUM
   77 CTHIN=CTHIN/STORE**NTHIN
      SUM(14)=SUM(14)+CTHIN
C     INCREMENT SUMS AND COUNTER TO FINAL VALUES
      TCOST=TCOST+T+TSCAR+CTHIN
      SUM(4)=SUM(4)+TCOST
      SUM(9)=SUM(9)+1.
C     IF REQUIRED FIND FUTURE PRICE
      IF(ICT.NE.1) FPRICE=YBAL(FP(5),BFP,CFP,RANDU,IX)
C     FIND FUTURE EXPECTED TOTAL COST AND INCREMENT SUM
      FC=(T+TSCAR+CTHIN)*STORE**(ROT-3*(INDCOM-1))
      SUM(13)=SUM(13)+FC
C
C     ESTIMATE NATURAL STAND VOLUME FOR SPECIES
C
    8 GO TO (14,15,16,17,18),ISP
   14 VOL=(-2313.8+2.2352*ROT*SI-.00018386*(ROT**2)*SI**2)/100.
      GO TO 19
   15 VOL=(-1775+125*SI*(EXP(-26.77/ROT)))/100.
      GO TO 19
   16 VOL=(-178.93+2.099*ROT*SI-0.00028896*ROT**2)/100.
      GO TO 19
   17 VOL=(-2595.6+2.6918*ROT*SI-0.3417*ROT**2)/100.
      GO TO 19
   18 VOL=(-1788+139.4*SI*(EXP(-28.77/ROT)))/100.
C     FIND VOLUME CONVERSION RATIO FOR PLANTATION OR NATURAL STAND
   19 IF(IND.EQ.2) RR=(-2435+181.2*SI*(EXP(-28.77/ROT)))/
     1              (-1788+139.4*SI*(EXP(-28.77/ROT)))
      IF(IND.LE.1) RR=1.0
C     FIND VOLUME ERROR TERM FOR PLANTATION OR NATURAL STAND
      IF(IND.LE.1) XCON=.05
      IF(IND.EQ.2) XCON=.017
C     ESTIMATE FINAL VOLUME
      VOL=VOL*RR+RANDN(IX,RANDU)*(VOL*XCON)
C     CONVERT VOLUME TO METRIC IF NECESSARY
      IF(SYSOUT.EQ.2) VOL=VOL*CONV3
C     FIND FUTURE VALUE FOR INTERNAL RATE OF RETURN CRITERION
      IF(ICT.EQ.4) FUTVAL=FPRICE*VOL*CFA*(STORE+(RANDN(IX,RANDU)*.2*
     1                    RINF))**((ROT-10)-3*(INDCOM-1))
C
      GO TO (82,83,83,84),ICT
C
C     BENEFIT COST RATIO
C     FIND PRESENT NET WORTH/TOTAL COST
   83 PNW=((FPRICE*VOL*CFA)*(STORE+(RANDN(IX,RANDU)*.2*RINF))**
     1   ((ROT-10)-3*(INDCOM-1))/STORE**(ROT-3*(INDCOM-1)))/TCOST
C
C     PRESENT NET WORTH
      IF(ICT.EQ.3) PNW=(PNW-1.)*TCOST
C     STORE RESULT FROM ITERATION
      ST(LOOP)=PNW
      GO TO 85
C
C     INTERNAL RATE OF RETURN
C     FIND RATE AND STORE RESULT FROM THIS ITERATION
   84 CALL FINDR(DISC)
      ST(LOOP)=DISC
      GO TO 85
C
C     COST EFFECTIVENESS
C     FIND AND STORE FUTURE COST/UNIT FROM THIS ITERATION
   82 ST(LOOP)=FC/(VOL*CFA)
   85 SUM(1)=SUM(1)+VOL*CFA
  100 CONTINUE
C
C     FIND  AVERAGE PER ITERATION
      IF(SUM(9).NE.0) SUM(14)=SUM(14)/SUM(9)
      IF(SUM(11).NE.0) SUM(12)=SUM(12)/NIT
```

```
      SUM(11)=SUM(11)/NIT
      IF(IND.LE.1) SUM(10)=SUM(10)/NIT
      DO 4 J=1,9
    4 SUM(J)=SUM(J)/NIT
      IF(SUM(12).GT.0) SUM(13)=SUM(13)+SUM(12)*STORE**(ROT-3*(INDCOM-1))
      SUM(13)=SUM(13)/(NIT*SUM(1))
C
C     SORT STORED VALUES FROM ITERATIONS
      CALL SORT(NIT,ST)
      IF(NM.NE.1) GO TO 44
C     FOR PROBABILITY FIND # CLASSES, INTERVAL AND VALUE FOR CLASS
      NCL=(100/PP)+1
      PD=PP/100.
   44 DO 20 I=1,NCL
      IF(NM.EQ.1) P(I)=(I-1)*PD
C     CHOOSE PERCENTILE VALUES AND STORE
   20 V(I)=ST((I-1)*NIT*PD+1)
      RETURN
      END
```

```
      SUBROUTINE YPAR(XL,XH,PL,PH,A,B,C)
C
C     THIS SUBROUTINE ESTIMATES THE SCALE (B) AND SHAPE (C) PARAMETERS
C     OF A 3 PARAMETER WEIBULL DISTRIBUTION FOR DESIRED VARIABLE FROM
C     INPUT SUBJECTIVE ESTIMATES WHERE ABSOLUTE MINIMUM AS VALUE OF
C     LOCATION PARAMETER (A).
C
C     XL - LOW ESTIMATE
C     XH - HIGH ESTIMATE
C     PL - PROBABILITY LESS THAN LOW ESTIMATE
C     PH - PROBABILITY LESS THAN HIGH ESTIMATE
C
      REAL*8 XL,XH,PL,PH,B,C,A
      C=(DLOG(DLOG(1.-PL)/DLOG(1.-PH)))/DLOG((XL-A)/(XH-A))
      B=DEXP((DLOG(XL-A)-DLOG(XH-A)*DLOG(-DLOG(1.-PL)))
     1 /(1.-DLOG(-DLOG(1.-PL))))
      RETURN
      END
```

```
      REAL FUNCTION YBAL(A,B,C,RANDU,IX)
C
C     THIS SUBROUTINE GENERATES A WEIBULL RANDOM VARIABLE VALUE FOR A
C     SPECIFIED SET OF PARAMETERS A,B,C.
C
C     A - LOCATION PARAMETER
C     B - SCALE PARAMETER
C     C - SHAPE PARAMETER
C
      REAL*8 A,B,C
      YBAL=(B*(-ALOG(1.-RANDU(IX)))**(1./C))+A
      RETURN
      END
```

```
      SUBROUTINE FINDR(R)
C
:     THIS SUBROUTINE FINDS INTERNAL RATE OF RETURN.  BINOMIALLY
C     SEARCHES FOR RATE WHICH MINIMIZES COST DIFFERENCE.
C
C     R - INTERNAL RATE OF RETURN
C     R1 - DIFFERENCE AT LOW SEARCH RATE
C     R2 - DIFFERENCE AT HIGH SEARCH RATE
C     SIGN - SIGN OF RATE POSITIVE OR NOT
C     RINC - RATE DIFFERENTIAL
C     RL - LOW SEARCH RATE
C     RH - HIGH SEARCH RATE
C     CR - LESSER OF COST DIFFERENCES AT LOW AND HIGH RATE
C
      LOGICAL SIGN
      R=0.0
      R1=DISCST(R)
      IF(ABS(R1).LT..5) RETURN
C     INITIALIZE RATE
      R=.20
C     ESTABLISH SIGN OF RATE
      SIGN=.TRUE.
      IF(R1.LT.0.0) R=-.20
      IF(R1.LT.0.0) SIGN=.FALSE.
C     FIND DIFFERENCE AT INITIAL RATE
      R2=DISCST(R)
      IF(ABS(R2).LT..5) RETURN
C     INITIALIZE RATE INCREMENT
      RINC=ABS(R)
      IF(R1*R2.LT.0.0) R=0.0
      DO 5 I=1,10
C     CALCULATE NEW RATE DIFFERENTIAL
      RINC=RINC/2.
C     SET NEW SEARCH RATES
      RL=R-RINC
      RH=R+RINC
C     FIND DIFFERENCES AT NEW RATES
      R1=DISCST(RL)
      R2=DISCST(RH)
C     FIND NEW RATE BY COMPARING DIFFERENCES
      IF(R1.LT.0. .AND. R2.LT.0.) GO TO 2
      IF(R1.GT.0. .AND. R2.GT.0.) GO TO 3
      IF(SIGN) GO TO 20
      GO TO 30
    2 R=RL
   20 CR=R1
      GO TO 4
    3 R=RH
   30 CR=R2
    4 IF(ABS(CR).LT..5) RETURN
    5 CONTINUE
      RETURN
      END
```

## APPENDIX I (concluded)

```
      REAL FUNCTION DISCST(RATE)
C
C     FUNCTION TO FIND DIFFERENCE BETWEEN FUTURE VALUE DISCOUNTED TO
C     PRESENT AND TOTAL OF COSTS DISCOUNTED TO PRESENT, BOTH AT RATE
C     OF RETURN RATE.
C
C     COSTS - COST
C     IYEAR - YEAR OF COST
C     ICNT - NUMBER OF COSTS
C     FUTVAL - FUTURE VALUE
C     IND - REGENERATION METHOD  1 - NATURAL OR SEEDING  2 - PLANTING
C     STORE - RATE OF RETURN
C     RINF - RATE OF INFLATION
C     RATE - INTERNAL INTEREST RATE
C
      DIMENSION COSTS(50), IYEAR(50)
      COMMON/BLK1/ COSTS, IYEAR, ICNT, FUTVAL, IND
      COMMON NIT,IX,PP,RINF,RT,ROT,NM
      DISCST=0.0
C     CALCULATE RATE OF RETURN
      STORE=1+RATE-RINF
C
C     FOR EACH COST
      DO 1 I=1, ICNT
C     DISCOUNT COST TO PRESENT AND SUM
    1 DISCST=DISCST+COSTS(I)/STORE**IYEAR(I)
C
C     FIND DIFFERENCE
      DISCST=FUTVAL/STORE**(ROT-3*(IND-1))-DISCST
      RETURN
      END
```

```
      REAL FUNCTION RANDN(IX,F)
C     THIS FUNCTION GENERATES A RANDOM NUMBER
C     FROM NORMAL DISTRIBUTION WITH MEAN = 0
C     AND STANDARD DEVIATION = 1.
      SD=1.
      AM=0.
      A=0.0
      DO 50 I=1,12
   50 A=A+F(IX)
      RANDN=(A-6.0)*SD+AM
      RETURN
      END
```

```
      REAL FUNCTION RANDU(IX)
C     THIS FUNCTION GENERATES A RANDOM NUMBER
C     FROM THE UNIFORM DISTRIBUTION BETWEEN 0 AND 1.
      IY=IX*65539
      IF(IY)5,6,6
    5 IY=IY+2147483647+1
    6 XR=IY
      RANDU=XR*.4656613E-9
      IX=IY
      RETURN
      END
```

```
      SUBROUTINE SORT(N,Z)
C
C     THIS SUBROUTINE ORDERS VECTOR Z IN ASCENDING ORDER BY BUBBLE SORT
C
      DIMENSION Z(5000)
      I=N
    1 K=0
      DO 2 J=2,I
      IF(Z(J)-Z(J-1))2,2,3
    3 V=Z(J)
      Z(J)=Z(J-1)
      Z(J-1)=V
      K=1
    2 CONTINUE
      I=I-1
      IF(K)4,4,1
    4 RETURN
      END
```

APPENDIX II

Description of INPUT variables for Simulator "REGEN"

| Section | Order | Description |
|---|---|---|
| I | | Run identification: Up to 80 alphanumeric characters, the first 40 of which might include the name and abbreviated address and the remainder of which might include identifying information regarding a run, e.g., Mr. R.J. Smith, OMNR, Thunder Bay. Run No. 2 revised estimates, July 25, 1976. |
| II | | General run control data |
| | 1 | Number of iterations or number of successful regeneration treatments to be compared |
| | 2 | Starting rotation age (years) |
| | 3 | End rotation age (years) |
| | 4 | Rotation age interval (years) |
| | 5 | Inflation rate (%) |
| | 6 | Probability interval for output (%) |
| | 7 | Low interest rate (%) |
| | 8 | High interest rate (%) |
| | 9 | Interest rate interval (%) |
| | 10 | Output option: 1 for short form (input echo and related statistics omitted); other than 1, detailed output |
| | 11 | Input data units code: 1 - English, 2 - metric |
| | 12 | Output data units code: 1 - English, 2 - metric |
| | 13 | Number of species involved in the run |
| | 14 | Number of economic criteria to be calculated for each species |

(continued)

Description of INPUT variables for Simulator "REGEN" (continued)

| Section | Order | Description |
|---|---|---|
| III | | Species data |
| | 1 | Species code: 1 - black spruce, 2 - jack pine, 3 - red pine, 4 - white pine, 5 - white spruce |
| | 2 | A stocking level above which regeneration is considered successful |
| | 3 | A stocking level at or below which regeneration is considered a failure |

To be followed by all data for each regeneration economic analysis for this species (Section IV) and then repeated for each species (if > 1).

| Section | Order | Description |
|---|---|---|
| IV | | Data for each regeneration economic analysis for species |
| a) | | Heading for species-regeneration system: 12 alphanumeric characters which might include species, regeneration system, and type of stock used, if applicable, e.g., PLANT WS 2-2 for planting white spruce transplants |
| b) | | Subjective estimates |
| (i | | Cost of regeneration (planting or seeding including stock or seed) |
| | 1 | Low estimate for cost of regeneration ($/unit of area) |
| | 2 | High estimate for cost of regeneration ($/unit of area) |
| | 3 | A probability that cost of regeneration might be less than the low estimate |
| | 4 | A probability that cost of regeneration might be less than the high estimate |
| | 5 | A minimum estimate for cost of regeneration. This must be less than the low estimate. ($/unit of area) |
| (ii | | Cost of scarification ($/unit of area) |
| | 1 | Low estimate for cost of scarification |
| | 2 | High estimate for cost of scarification |

(continued)

Description of INPUT variables for Simulator "REGEN" (continued)

| Section | Order | Description |
|---|---|---|
| | 3 | A probability that cost of scarification might be < low estimate |
| | 4 | A probability that cost of scarification might be < high estimate |
| | 5 | A minimum estimate for cost of scarification ( < low estimate) |
| (iii | | Cost of thinning ($/unit of area) |
| | 1 | Low estimate for cost of thinning |
| | 2 | High estimate for cost of thinning |
| | 3 | A probability that cost of thinning might be < low estimate |
| | 4 | A probability that cost of thinning might be < high estimate |
| | 5 | A minimum estimate for cost of thinning ( < low estimate) |
| (iv | | Stocking |
| | 1 | Low stocking estimate |
| | 2 | High stocking estimate |
| | 3 | A probability that stocking might be < low estimate |
| | 4 | A probability that stocking might be < high estimate |
| | 5 | A minimum stocking level (< low estimate) |
| c) | | Control data (levels, ages, options) |
| | 1 | Site index |
| | 2 | Number of possible complete and/or partial regeneration trials/scarification |
| | 3 | Maximum number of scarifications per regeneration system |

(continued)

APPENDIX II (continued)

Description of INPUT variables for Simulator "REGEN" (concluded)

| Section | Order | Description |
|---|---|---|
| | 4 | Regeneration survey, i.e., years after regeneration |
| | 5 | Probability that a regenerated stand may be thinned |
| | 6 | Low thinning age |
| | 7 | High thinning age |
| | 8 | Method of regeneration: 0 - natural regeneration, 1 - seeding, 2 - planting |
| | 9 | Code for economic criterion to be used: 1 - cost-effectiveness, 2 - benefit:cost ratio, 3 - present net worth, 4 - internal rate of return |
| d) | | Optional input |
| (i | | Probability that a site might be regenerated from slash - for seeding only |
| (ii | | Subjective estimates for future prices per unit of volume - not required if economic criterion code 1 is used |
| | 1 | Low estimate of future price per unit of volume 10 years hence |
| | 2 | High estimate of future price per unit of volume 10 years hence |
| | 3 | A probability that the future price might be < low estimate |
| | 4 | A probability that the future price might be < high estimate |
| | 5 | A minimum future price per unit of volume ( < low estimate) |
| V | | Random number generator starter, i.e., any integer no. up to 9 digits |
| | | Data format - all numeric data separated by blank(s) and/or comma |

# APPENDIX II (continued)

## An example of INPUT DATA

Section

I MR. R.J. SMITH, OMNR, THUNDER BAY. RUN NO. 2 REVISED ESTIMATES, JULY 25, 1975.

II 100, 40, 80, 20, .05, 10., 8, 10, 2, 0, 1, 2, 3, 1, 2, 1

III 5 .70 .45

IV a) PLANTING SW

b)

| | LOW | HIGH | PROB. < LOW | PROB. < HIGH | MINIMUM |
|---|---|---|---|---|---|
| (i | 65 | 100 | .05 | .95 | 55 |
| (ii | 10 | 25 | .05 | .8 | 8 |
| (iii | 4 | 12 | .1 | .8 | 3 |
| (iv | .4 | .95 | .05 | .9 | .3 |

c) 70. 2 2 2 .05 10. 25. 2 1

III 2 .65 .4

IV a) PLANT JP

b)

| | LOW | HIGH | PROB. < LOW | PROB. < HIGH | MINIMUM |
|---|---|---|---|---|---|
| (i | 47.5 | 80 | .1 | .81 | 25.7 |
| (ii | 17.3 | 29 | .13 | .79 | 14.1 |
| (iii | 5.1 | 15.9 | .18 | .82 | 3.1 |
| (iv | .38 | .89 | .26 | .86 | .24 |

c) 60. 3 2 2 .1 15. 25. 2 1

d)
(ii

IV a) SEEDING JP

b)

| | LOW | HIGH | PROB. < LOW | PROB. < HIGH | MINIMUM |
|---|---|---|---|---|---|
| (i | 7.6 | 14.7 | .14 | .78 | 5.5 |
| (ii | 17.7 | 33.7 | .14 | .79 | 15.6 |
| (iii | 6.4 | 20.7 | .16 | .79 | 3.9 |
| (iv | .21 | .86 | .26 | .83 | .17 |

c) 55. 2 2 3 .2 20. 35. 1 3

d)

| | | | | | |
|---|---|---|---|---|---|
| (i | .2 | | | | |
| (ii | 7 | 9 | .1 | .8 | 6.5 |

III 1 .50 .40

IV a) SEEDING SB

b)

| | LOW | HIGH | PROB. < LOW | PROB. < HIGH | MINIMUM |
|---|---|---|---|---|---|
| (i | 8. | 15. | .20 | .95 | 5. |
| (ii | 25. | 35. | .10 | .90 | 15. |
| (iii | 15. | 35. | .10 | .95 | 8. |
| (iv | .10 | .75 | .25 | .95 | .02 |

c) 36. 2 2 3 .25 25. 35. 1 4

d)

| | | | | | |
|---|---|---|---|---|---|
| (i | .10 | | | | |
| (ii | 6 | 8 | .05 | .9 | 5.5 |

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## APPENDIX II (concluded)

### Input data form for simulator "REGEN"

Section

I ______

II ____ ____ ____ ____ ____ ____ .... .... ....

III ____ ____ ____

IV
a) ______

| b) | LOW | HIGH | PROB. < LOW | PROB. < HIGH | MINIMUM |
|---|---|---|---|---|---|
| (i | | | | | |
| (ii | | | | | |
| (iii | | | | | |
| (iv | | | | | |

c) ____ ____ ____ ____ ____ ____ ____ ____ ____

d) (i ______

| (ii | | | | | |
|---|---|---|---|---|---|

III ____ ____ ____

IV
a) ______

| b) | | | | | |
|---|---|---|---|---|---|
| (i | | | | | |
| (ii | | | | | |
| (iii | | | | | |
| (iv | | | | | |

c) ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

d) (i ______

| (ii | | | | | |
|---|---|---|---|---|---|

III ____ ____ ____

IV
a) ______

| b) | | | | | |
|---|---|---|---|---|---|
| (i | | | | | |
| (ii | | | | | |
| (iii | | | | | |
| (iv | | | | | |

c) ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

d) (i ______

| (ii | | | | | |
|---|---|---|---|---|---|

III ____ ____ ____

IV
a) ______

| b) | | | | | |
|---|---|---|---|---|---|
| (i | | | | | |
| (ii | | | | | |
| (iii | | | | | |
| (iv | | | | | |

c) ____ ____ ____ ____ ____ ____ ____ ____ ____

d) (i ______

| (ii | | | | | |
|---|---|---|---|---|---|

V ______

# APPENDIX III

Completed input form for example no. 1

Section

I Four regen. systems, criterion 1, revised estimates, run no. 3, 5/17/77

II 250 50 75 25 .05 10. 9 12 3 5 2 2 4 1 1 ..1.. ..1.. ....

III 2 .7 .40

IV a) Seeding PJ

| b) | LOW | HIGH | PROB. < LOW | PROB. < HIGH | MINIMUM |
|---|---|---|---|---|---|
| (i | 20 | 40 | .15 | .8 | .15 |
| (ii | 45 | 85 | .15 | .8 | 40 |
| (iii | 15 | 50 | .15 | .8 | 10 |
| (iv | .2 | .85 | .25 | .85 | .15 |

c) 15. 2 2 3 .2 20. 35. 1 1

d) (i .15

(ii

III 2 .65 .4

IV a) Planting PJ

| b) | | | | | |
|---|---|---|---|---|---|
| (i | 120 | 200 | .1 | .8 | 65 |
| (ii | 45 | 70 | .15 | .8 | 35 |
| (iii | 15 | 40 | .2 | .8 | 8 |
| (iv | .35 | .9 | .25 | .85 | .25 |

c) 18. 3 2 2 .1 15. 25. 2 1

d) (i

(ii

III 5 .7 .45

IV a) Planting SW

| b) | | | | | |
|---|---|---|---|---|---|
| (i | 150 | 250 | .05 | .95 | 135 |
| (ii | 25 | 60 | .05 | .8 | 20 |
| (iii | 10 | 30 | .1 | .8 | 7.5 |
| (iv | .4 | .95 | .05 | .9 | .3 |

c) 20. 2 2 2 .05 10. 25. 2 1

d) (i

(ii

III 1 .55 .45

IV a) Planting SB

| b) | | | | | |
|---|---|---|---|---|---|
| (i | 125 | 225 | .1 | .8 | 110 |
| (ii | 30 | 60 | .1 | .9 | 25 |
| (iii | 20 | 35 | .1 | .9 | 15 |
| (iv | .4 | .8 | .2 | .7 | .1 |

c) 13. 3 3 2 .1 15. 25. 2 1

d) (i

(ii

V 12345

# APPENDIX III (concluded)

## Completed input form for example no. 2

Section

I — Three region systems, criterion 4, revised estimates, run no. 2, 618177

II — 250 50 75 25 .05 20. 9 12 3 5 2 2 3 1 1 .... .... ....

III — 2 .65 .4

IV

a) Planting PJ

b)

| | LOW | HIGH | PROB. < LOW | PROB. < HIGH | MINIMUM |
|---|---|---|---|---|---|
| (i | 120 | 200 | .1 | .8 | 65 |
| (ii | 45 | 70 | .15 | .8 | 35 |
| (iii | 15 | 40 | .2 | .8 | 8 |
| (iv | .35 | .9 | .25 | .85 | .25 |

c) 18. 3 2 2 .1 15. 25. 2 4

d) (i

| | | | | | |
|---|---|---|---|---|---|
| (ii | 2.5 | 3.0 | .2 | .8 | 2.0 |

III — 5 .7 .45

IV

a) Planting SW

| | | | | | |
|---|---|---|---|---|---|
| b) (i | 150 | 250 | .05 | .95 | 135 |
| (ii | 25 | 60 | .05 | .8 | 20 |
| (iii | 10 | 30 | .1 | .8 | 7.5 |
| (iv | .4 | .95 | .05 | .9 | .3 |

c) 20. 2 2 2 .05 10. 25. 2 4

d) (i

| | | | | | |
|---|---|---|---|---|---|
| (ii | 3.0 | 3.5 | .2 | .8 | 2.5 |

III — 1 .5 .45

IV

a) Planting SB

| | | | | | |
|---|---|---|---|---|---|
| b) (i | 125 | 225 | .1 | .8 | 110 |
| (ii | 30 | 60 | .1 | .9 | 25 |
| (iii | 20 | 35 | .1 | .9 | 15 |
| (iv | .4 | .8 | .2 | .7 | .1 |

c) 13. 3 3 2 .1 15. 25. 2 4

d) (i

| | | | | | |
|---|---|---|---|---|---|
| (ii | 2.5 | 3.0 | .2 | .8 | 2.0 |

III — ___ ___ ___

IV

a)

| | | | | | |
|---|---|---|---|---|---|
| b) (i | | | | | |
| (ii | | | | | |
| (iii | | | | | |
| (iv | | | | | |

c)

d) (i

| | | | | | |
|---|---|---|---|---|---|
| (ii | | | | | |

V — 79413