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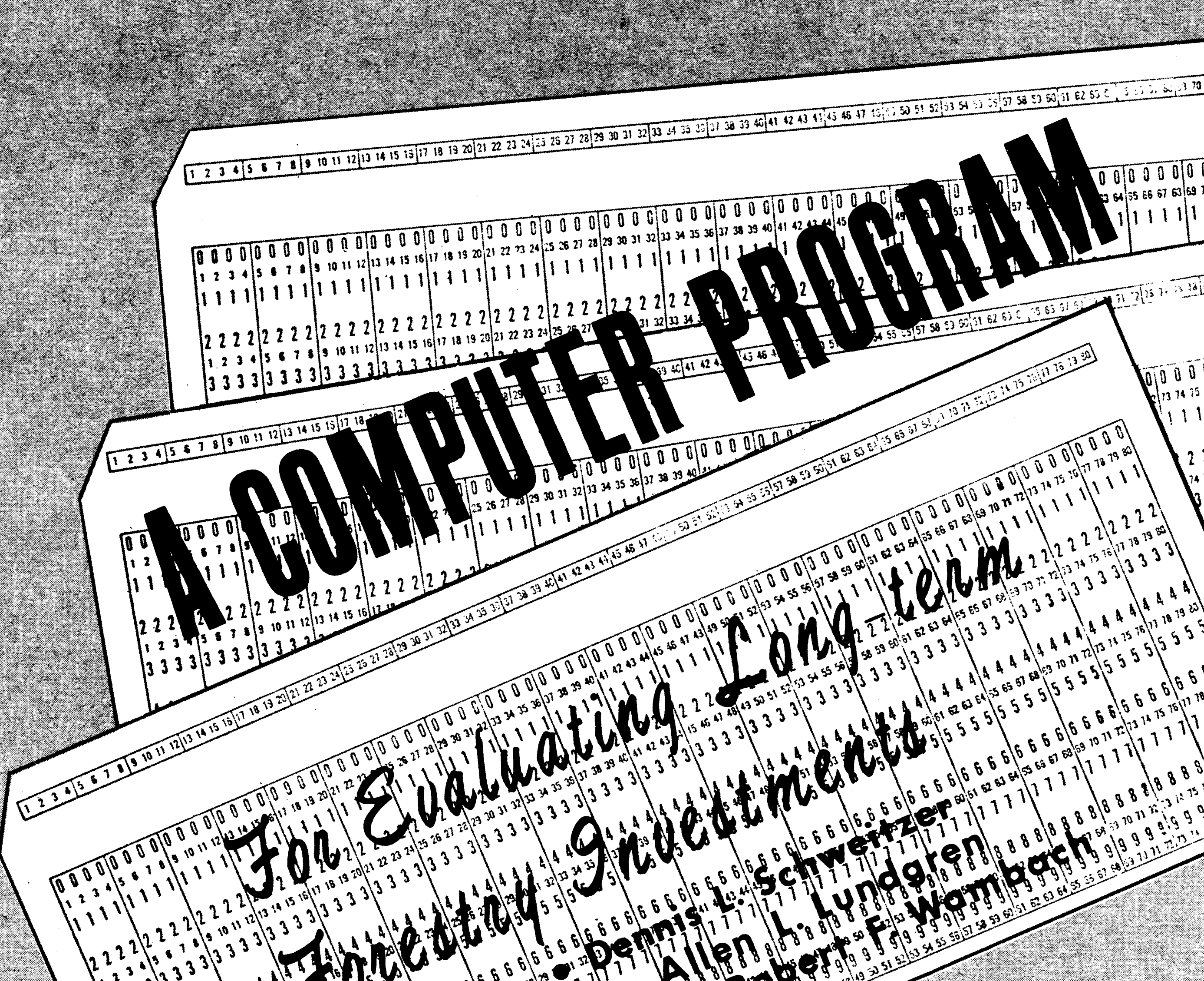

A COMPUTER PROGRAM

For Evaluating Long-term Forestry Investments

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WHAT THIS PROGRAM DOES

Evaluating long-term investments such as those common to forestry is tedious and time-consuming. Because we generally put all costs and incomes on a common basis by compounding or discounting to some fixed point in time, the calculations are often so involved that only a few alternatives can be examined.

The computer program presented in this paper reduces the cost and time required for evaluating investments and permits more thorough searches for "best" answers. It differs from other published programs oriented to forestry[1] in that problems of greater complexity can be solved and solutions to straightforward problems can be found more easily.

As an illustration, consider the problem faced by a manager evaluating an investment opportunity in growing red pine. He expects the following yields:

Age (years)	*Average yield per acre (cords)*	*Type of cut*
25	8.1	Thinning
35	12.2	Thinning
45	13.9	Thinning
55	14.7	Thinning
65	43.6	Clear cut

His best guess is that stumpage will bring about \$3.80 per cord. In addition, he can count on \$.20 per acre from hunting leases. On the other hand, expected costs include an annual \$.50 per acre for taxes and general administration, \$40 in establishment costs, and \$4.20 for release by aerial spraying after 3 years. If he feels a discount rate of 5 percent is appropriate, should he invest money in this enterprise?

Following the methods and rules presented in this paper, this problem can be summarized and entered onto 14 punched cards in a form the computer can recognize and use to generate the correct answer (fig. 1). (The manager would learn this is not a good use for his money — at best, he would earn about 4 percent on this investment.)

This type of appraisal is one use for the NCRETURN[2] program. We can obtain discounted costs and incomes to see if a particular opportunity promises to be a good investment. We might be interested in investing our money only if we expect incomes to exceed costs when both are discounted at some rate. Alternatively, we could use the internal rate of return (IRR) as our basis for decision, where the IRR is defined as that discount rate at which discounted income equals discounted costs. If the potential investment has an IRR of less than our required rate, we would reject this investment. The basis for an evaluation under either criterion is provided by the computer.

Perhaps the weakest link in evaluating long-term investments is predicting future prices. It is often helpful to evaluate an opportunity under a series of price assumptions. For example, the red pine problem might be rerun using prices of \$4.50 and \$5.00 per cord. For each new price, we would have to add just two punched cards to those pictured in figure 1. In a similar manner, any other income or cost assumptions can be altered.

Comparisons may also be made between completely different investment opportunities. We might wish to compare the financial returns from good and poor sites, from red pine saw logs and jack pine pulpwood grown on the same site, or from single-use and multiple-use management. In

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[1] *See, for example: Hall, O. F. Evaluating complex investments in forestry and other long-term enterprises using a digital computer. Purdue Univ. Res. Bull. 752, 11 pp., illus., 1962; or Row, Clark. Determining forest investment rates-of-return by electronic computer. U.S. Forest Serv. Res. Pap. SO-6, 13 pp., illus. 1963. S. Forest Exp. Sta., New Orleans, La.*

[2] *The code word used to identify this program. "NC" stands for North Central Forest Experiment Station. "RETURN" stands for investment returns.*

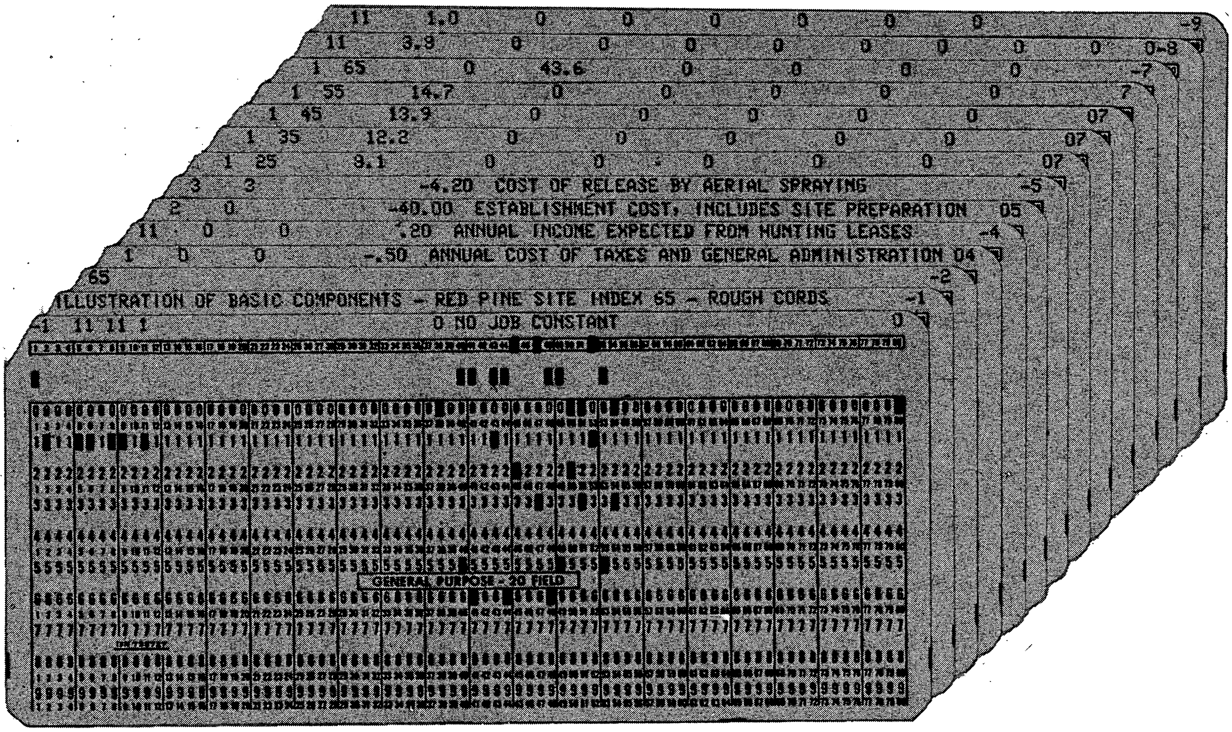

FIGURE 1. — These 14 punched cards were prepared to obtain a computer solution to a problem in managing red pine.

such cases the alternatives can be analyzed separately and comparisons made by means of the calculated discounted values or internal rates of return.

Although the program was written specifically to evaluate the common investment problem of growing timber for a full rotation, it can also assess other types of investments. The reader should realize that the labels used in the following discussion are arbitrary symbols for variables in fixed arithmetic operations. The red pine yields of the sample problem, for example, could be the output of a processing mill as readily as that of a forest.

This program will provide no magical answers to problems. Although the results of even the most complex analyses will be arithmetically correct, they will be no more valid than the data on which they are based. The computer does what the analyst might otherwise do by hand, but it does the job more accurately, rapidly, and cheaply.

The paper presents: first, those features of the program that are of most general interest; second, options such as punched card output that permit flexibility in analyses; third, the rules to be followed in translating problems into "computer talk" via punched cards; and finally, some of the more highly specialized uses of the program. An appendix contains the documentation required to adapt it to a particular computer.

COMPONENTS OF THE PROGRAM

The NCRETURN program provides a basis for choosing among possible investments, given the costs and incomes expected from each. A variety of input information can be specified, but the simple red pine example given in the introduction illustrates those elements of the program that are likely to be of the greatest general interest.

Illustration of Basic Components

Figure 2 pictures the computer printout triggered by the punched cards shown in figure 1. Sections 1 to 5 of the printout constitute the input — the information fed to the computer. The computer has listed the one-time and recurring costs and incomes, the physical yield volumes (in rough cords), and price and quality functions. Sections 6 and 7 constitute the output — the information requested of the computer. It has multiplied the individual yields by the price function and those results by the quality function, and has printed the dollar values; it has discounted all of these costs and incomes to age zero and printed the discounted costs, incomes, and net worths for a range of discount rates; and it has computed and printed the internal rate of return.

The problem is identified in section 1. We see that we are dealing with red pine growing on site 65 land, and that our economic analysis will be concerned only with rough cords of wood. There is no limit to the amount of such descriptive information that can be entered into the program.

Section 2 is the *Income and Cost Schedule*. Listed are all annual and single (one-time) costs and incomes, along with the ages of occurrence and a brief description of each item.[3] Included are one annual cost to cover taxes and general administration, an annual income expected from the sale of hunting rights, an initial cost for establishment, and a release cost that will be required after 3 years. It is assumed that all annuities (annual payments) will run from establishment until the end of the rotation in equal payments since no entries occur under *Age* — the year of the last payment — or *Annual Change*. Costs are listed as negative values and incomes as positive values. The arbitrary entries under *Item* are for the convenience of the user in identifying inputs to the problem.

Section 3 is the *Schedule of Physical Yields* — a list of timber products expected at various ages. The four *Factors* provide a means of entering other physical data (such as diameters or heights) associated with each physical yield; these will be discussed later in the context of particular applications.

Our example assumes a constant price of $3.80 per cord, but the *Price Function Coefficients* permit considering more complex situations. Similarly, we could explicitly consider variations in quality through the *Quality Function Coefficients*. In this example, we have "neutralized" quality by entering a value of one.

In the *Value of Physical Yields* schedule, the physical yields from section 3 have been multiplied by the price and quality functions and the resulting dollar values printed. Where the previous sections were simply listings of input information provided to the computer, this table is an intermediate calculated output.

The final section in figure 2, the *Table of Discounted Values,* is a listing of the financial yield information generated by the computer. Each of the income and cost items listed in sections 2 and 6 has been discounted to age zero, using a series of discount rates; and the discounted net worth has been calculated by algebraically summing the discounted incomes and costs. Also included in the table is the exact discount rate (to the nearest 100th of a percent) at which discounted income equals discounted costs, the internal rate of return (IRR). From these values we could say, for instance, that for a discount rate of 3 percent the investment provided a residual value of $28.01. Or we could say that we had earned or might earn a 4.05-percent return on our invested monies. Clearly a rate of 5 percent cannot be expected from this particular investment.

With this over-view, we can now examine the program in more depth.

Multiple Products

In the red pine example, we considered only one product. However, we often must consider several, such as pulpwood, sawtimber, poles, man-days of hunting, or acre-feet of water. As many as nine products can be entered into the NCRETURN program, where the physical yields and ages of occurrence of each would be listed in the *Schedule of Physical Yields*.

This program feature is flexible. "Product" can be thought of as any component of yield for which we want to use a separate price or quality function. For instance, we might choose to classify as different products spruce cordwood and jack pine cordwood, grade 2 logs and grade 3 logs, or 30-foot poles and 40-foot poles.

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[3] *The E-field notation appearing in the column of Income or Cost in section 2 and used for much of the computer printout may not be familiar to some readers. The symbol E+xx following a number indicates that the number is to be interpreted after moving the decimal point xx places to the right. Similarly, E-xx implies that the decimal should be moved xx places to the left. The incomes and costs in figure 2, then, would be interpreted at $.50 annual taxes, $.20 annual income from hunting rights, $40.00 establishment cost, and $4.20 release cost.*

NORTH CENTRAL FOREST EXPERIMENT STATION (U.S.D.A.)
PROGRAM NCRETURN

PROBLEM NO. 2

1

ILLUSTRATION OF BASIC COMPONENTS - RED PINE SITE INDEX 65 = ROUGH CORDS
0 NO JOB CONSTANT

INCOME AND COST SCHEDULE

2

TYPE	ITEM	AGE	ANNUAL CHANGE	INCOME OR COST	DESCRIPTION
ANNUAL	1	0	0	-.500000E+00	ANNUAL COST OF TAXES AND GENERAL ADMINISTRATION
ANNUAL	11	0	0	.200000E+00	ANNUAL INCOME EXPECTED FROM HUNTING LEASES
SINGLE	2	0		-.400000E+02	ESTABLISHMENT COST, INCLUDES SITE PREPARATION
SINGLE	3	3.		-.420000E+01	COST OF RELEASE BY AERIAL SPRAYING

SCHEDULE OF PHYSICAL YIELDS

3

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
YIELD	1.	25.	.810000E+01	0	0	0	0	0
YIELD	1.	35.	.122000E+02	0	0	0	0	0
YIELD	1.	45.	.139000E+02	0	0	0	0	0
YIELD	1.	55.	.147000E+02	0	0	0	0	0
YIELD	1.	65.	0	.436000E+02	0	0	0	0

PRICE FUNCTION COEFFICIENTS

4

PFID	PROD	CONSTANT	FACTOR 1	(FACTOR 1) SQUARED	AGE	(AGE) SQUARED	(AGE) * (FACTOR 1)	JOB CONSTANT	(JOB CON.) SQUARED	(AGE) * (JOB CON.)	DR
1	1	.38000E+01	0	0	0	0	0	0	0	0	0

QUALITY FUNCTION COEFFICIENTS

5

PFID	PROD	CONSTANT	FACTOR 2	(FACTOR 2) SQUARED	FACTOR 3	(FACTOR 2)* (FACTOR 3)	FACTOR 4	(FACTOR 3)* (FACTOR 4)
1	1	.10000E+01	0	0	0	0	0	0

VALUE OF PHYSICAL YIELDS (PHYSICAL YIELD * PRICE * QUALITY)

6

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD
YIELD	1	25.	.307800E+02	0
YIELD	1	35.	.463600E+02	0
YIELD	1	45.	.528200E+02	0
YIELD	1	55.	.558600E+02	0
YIELD	1	65.	0	.165680E+03

.....ROTATION LENGTH = 65 YEARS.....

RL NO. 1 OF 1 - PROBLEM NO. 2

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

7

	DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR
	.0050	281.647	-71.826	209.820	.3611578E+01
	.0100	219.096	-67.890	151.207	.2099667E+01
	.0150	171.619	-64.685	106.934	.1612729E+01
	.0200	135.382	-62.056	73.325	.1381312E+01
	.0250	107.564	-59.882	47.682	.1251385E+01
	.0300	86.084	-58.070	28.014	.1171527E+01
	.0350	69.396	-56.547	12.849	.1119664E+01
	.0400	56.352	-55.257	1.095	.1084755E+01
IRR =	.0405	55.100	-55.127	-.027	.1081934E+01
	.0450	46.092	-54.156	-8.064	.1060677E+01
	.0500	37.971	-53.209	-15.237	.1043783E+01
	.0550	31.503	-52.388	-20.885	.1031782E+01
	.0600	26.318	-51.671	-25.353	.1023178E+01
	.0650	22.135	-51.041	-28.906	.1016966E+01

FIGURE 2. — The red pine problem as an illustration of the basic components of the NCRETURN program.

Price Function

The value of the physical yield is determined by multiplying volume by its expected price. In this example, we use a constant price of $3.80 per cord by entering that number under the *Price Function Coefficient* labeled *Constant.* Then the value of the intermediate yield, say, at 45 years is given by

Section 6 of figure 2		*Section 3*		*Section 4*
Value of physical yield at age 45	=	volume at age 45	x	price per unit
$52.82	=	(13.9 cords)	x	($3.80/cord)

Sometimes a constant unit price is not applicable. For example, it might be more realistic to value large trees more highly than small ones. If stand value varies with average DBH (diameter at breast height), for example, the price per cord might better be expressed in a more complex fashion such as

$$\text{price per cord} = \$[.5\,(\text{DBH}) - 1]$$

Since -1 is a constant, it would be entered under *Constant* in the price function. Average stand DBH, on the other hand, varies with the time of harvest. Therefore, the expected average DBH's at 25, 35, 45, 55, and 65 years would be entered next to the corresponding yields under the heading *Factor 1* in the *Schedule of Physical Yields.* If .5 is entered in the price function as the coefficient of *Factor 1,* the value of the yield at age 45 can be estimated under this price assumption. Given an average stand DBH of 9.7 inches, that value would be

$$\begin{aligned}
\text{value of yield at age 45} &= (\text{volume})\ (\text{price per unit}) \\
&= (\text{volume})\ [\text{Constant} + .5\,(\text{Factor 1})] \\
&= (\text{volume})\ [-1 + .5\,(\text{DBH}_{45})] \\
\$53.52 &= (13.9)\ [-1 + .5(9.7)]
\end{aligned}$$

It is possible to consider even more complex price functions. In the extreme, we could have

$$\begin{aligned}
\text{price} = [\ & a + b(\text{Factor 1}) + c(\text{Factor 1})^2 \\
& + d(\text{Age}) + e(\text{Age})^2 \\
& + f(\text{Age})(\text{Factor 1}) \\
& + g(\text{Job Constant}) \\
& + h(\text{Job Constant})^2 \\
& + i(\text{Age})(\text{Job Constant})]\ \times \\
& [(1 + dr)^{\text{Age}}\ ].
\end{aligned}$$

The letters *a, b, c,* etc., are the *Price Function Coefficients* of section 4 in figure 2. If a coefficient is not specified, that term will drop out of the function.

Age is similar to *Factor 1* in that it varies with the harvest considered. Since it already appears in the *Schedule,* entering appropriate coefficients will cause this variable to affect price. In contrast, the *Job Constant* is a constant for a particular problem. It appears on the last line of descriptive information (section 1) and is zero for this problem.

The last element that may be used in the price function is the *dr* factor. The *dr* is simply a decimal fraction that designates a percent change in price over time. It may be either positive or negative. For instance, if we expect that prices will increase at the rate of 2 percent per year, our price function would be of the form:

$$\text{price} = (\text{unadjusted price})\ (1 + .02)^{\text{Age}}$$

Finally, the *PFID* (price function identification) code is an optional means of identifying the group of price functions entered in a problem. It provides a simple means of tagging functions when, for example, a sequence of changing price assumptions are applied to the same physical data. The *QFID* (quality function identification) code serves the same purpose for quality functions.

Quality Function

While it is true that the products of volumes and the price function are the yield values in this instance, that value is actually found from the more complex relationship

$$\text{value} = (\text{volume})\ (\text{price function})\ (\text{quality function}).$$

In this example, quality was "neutralized" by being set equal to one. Although this function is arithmetically just an extension of the price function, it is kept separate for convenience.

The quality function may consist of a constant and various forms of three other variables, labeled *Factor 2, Factor 3,* and *Factor 4.* These variables, which are used exactly as *Factor 1* is used in the price function, might be any that affect value because of differences in product quality, such as tree taper, cull percent, water purity, or esthetic qualities. In the extreme, the function could include all the variables indicated in the printout under *Quality Function Coefficients.* When these *Factors* are used, they are individually listed opposite their corresponding entries in the *Schedule of Physical Yields.*

Rotation Length and Age

Rotation Length is printed at the beginning of the *Table of Discounted Values.* Because we are ordinarily interested in evaluating a schedule of activities beginning with stand establishment and running through some final harvest, this term is used in place of "period of investment." Similarly, *Age* refers to the number of years that will elapse after stand establishment — from the time the first money is invested — until a cost or income or some other event occurs. A discussion of how problems might be handled when biological and investment ages do not coincide appears in the section on Special Problems.

Perpetual Series of Rotations

One part of the sample output shown in figure 2 still remains to be explained. This is the column identified as *Infinite Rotations Adjustment Factor* found in section 7 of the *Table of Discounted Values*. This factor is defined by the expression

$$(1+p)^n/[(1+p)^n-1]$$

where p is a discount rate and n is the rotation length in years.

Multiplying this factor by the discounted net worth gives the soil or land expectation value (LEV) by making the necessary adjustment for a perpetual series of rotations. This assumes that the exact pattern of incomes and costs in the first rotation will be repeated in the succeeding rotations. The usefulness and application of LEV is described in many basic textbooks on the subject of valuations.[4] When making comparisons between investment alternatives, it may be necessary to use LEV rather than discounted net worth if the discount rate is low or if there is a sizable difference in rotation lengths between the alternatives.[5]

This adjustment in the expected value is not appropriate if future rotations will have a different pattern of incomes or costs. In the context of the NCRETURN program, for example, it is not valid to multiply this constant by the discounted net worth if —

(1) price is a function of time and the *dr* factor is used in the price function,
(2) any annuity is a function of time, or
(3) no allowance is made for investment values left at the end of the rotation (the terminal value).

[4] *See, for example: Hiley, W. E. Economics of plantations. 216 pp., illus. 1956. London: Faber and Faber, Ltd.; or Davis, Kenneth P. American forest management. 482 pp., illus. 1954. New York: McGraw-Hill Book Co., Inc.*

[5] *Lundgren, Allen L. Estimating investment returns from growing red pine. U. S. Forest Serv. Res. Pap. NC-2, 48 pp., illus. 1966. N. Cent. Forest Exp. Sta., St. Paul, Minn.*

Terminal Values

The printed discounted costs, incomes, and net worths are based on costs and incomes for only one rotation. Some of the expenditures considered in the analysis may be for land purchase, permanent improvement to the land, or other capital improvements that are expected to have some value left at the end of the rotation. To call attention to this easily overlooked value, a special terminal value input card is provided.

Revised Illustration

As a summary of the program features discussed, a revised version of the red pine problem is given in figure 3. The descriptive material has been expanded to include definitions of the *Factors* and the two products considered here. Note that the product codes, 2 and 3, occur in four different parts of the printout. Each product is tied to its own price and quality functions so the *Value of Physical Yields* table can be calculated. From this printout, for example, we can determine how the value of the pulpwood (product number 2) harvested at age 25 was found.

Value of pulpwood intermediate yield at 25 years.	=	(25-year pulpwood yield) x (pulpwood price function) x (pulpwood quality function)
	=	(25-year pulpwood intermediate yield) x [constant + (coefficient for factor 1) (factor 1)] x [constant + (coefficient for factor 2) (factor 2)]

$$\$13.78 = [7.4] \times [-1.0 + .5\ (5.8)] \times [0.3 + 0.02\ (34.0)]$$

Other changes in the problem include the addition of a charge for land purchase and its subsequent recovery (the terminal value) at the end of the rotation. All of these modifications are reflected in the *Table of Discounted Values*. By comparing this table with that in figure 2, we see this revised schedule would be a more attractive investment in terms of both the internal rate of return and discounted net worth for all discount rates less than 6 percent.

NORTH CENTRAL FOREST EXPERIMENT STATION (U.S.D.A.)
PROGRAM NCRETURN

PROBLEM NO. 3

REVISED RED PINE PROBLEM
SITE INDEX 65 THINNED TO 90 SQ.FT. B.A. EVERY 10 YEARS
800 TREES AND 148 SQ.FT. B.A. BEFORE THINNING, AGE 25
PRODUCT 2 = ROUGH CORDS PER ACRE TO A 3-INCH TOP D.I.B.
PRODUCT 3 = THOUSANDS OF BD.FT. PER ACRE, INTL. 1/4-INCH, TO 6-INCH TOP
FACTOR 1 = D.B.H. OF TREE OF AVERAGE B.A.
FACTOR 2 = TOTAL HEIGHT OF STAND
FACTOR 4 = PROPORTION SAWLOG VOLUME THAT IS CULL
800 TREES SITE65 BA90SQFT
OUTPUT ON PUNCHED CARDS

INCOME AND COST SCHEDULE

TYPE	ITEM	AGE	ANNUAL CHANGE	INCOME OR COST	DESCRIPTION
ANNUAL	1	0	0	-.500000E+00	ANNUAL COST
ANNUAL	11	0	0	.200000E+00	ANNUAL INCOME
SINGLE	2	0		-.400000E+02	ESTABLISHMENT COST
SINGLE	3	3.		-.420000E+01	RELEASE COST
SINGLE	4	0		-.100000E+02	LAND PURCHASE
TERMINAL	5			.100000E+02	LAND SALE AT END OF ROTATION

SCHEDULE OF PHYSICAL YIELDS

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
YIELD	2.	25.	.740000E+01	0	.580000E+01	.340000E+02	0	0
YIELD	2.	35.	.118000E+02	0	.760000E+01	.475000E+02	0	0
YIELD	2.	45.	.430000E+01	0	.970000E+01	.595000E+02	0	0
YIELD	3.	45.	.491000E+01	0	.970000E+01	.595000E+02	0	0
YIELD	3.	55.	.731000E+01	0	.122000E+02	.700000E+02	0	0
YIELD	3.	65.	.836000E+01	0	.150000E+02	.785000E+02	0	.100000E-01
YIELD	3.	75.	.905000E+01	0	.181000E+02	.855000E+02	0	.300000E-01
YIELD	3.	85.	0	.313200E+02	.214000E+02	.920000E+02	0	.500000E-01

PRICE FUNCTION COEFFICIENTS

PFID	PROD	CONSTANT	FACTOR 1	(FACTOR 1) SQUARED	AGE	(AGE) SQUARED	(AGE) * (FACTOR 1)	JOB CONSTANT	(JOB CON.) SQUARED	(AGE) * (JOB CON.)	DR
PF3	2	-.10000E+01	.50000E+00	0	0	0	0	0	0	0	0
PF3	3	-.30000E+02	.50000E+01	-.10000E+00	0	0	0	0	0	0	0

QUALITY FUNCTION COEFFICIENTS

QFID	PROD	CONSTANT	FACTOR 2	(FACTOR 2) SQUARED	FACTOR 3	(FACTOR 2)* (FACTOR 3)	FACTOR 4	(FACTOR 3)* (FACTOR 4)
QF3	2	.30000E+00	.20000E-01	0	0	0	0	0
QF3	3	.10000E+01	0	0	0	0	-.10000E+01	0

VALUE OF PHYSICAL YIELDS (PHYSICAL YIELD * PRICE * QUALITY)

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD
YIELD	2	25.	.137788E+02	0
YIELD	2	35.	.413000E+02	0
YIELD	2	45.	.246670E+02	0
YIELD	3	45.	.446368E+02	0
YIELD	3	55.	.117808E+03	0
YIELD	3	65.	.186219E+03	0
YIELD	3	75.	.243507E+03	0
YIELD	3	85.	0	.928444E+03

.....ROTATION LENGTH = 85 YEARS.....

RL NO. 1 OF 1 - PROBLEM NO. 3

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

	DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR
	.0050	1121.936	-88.691	1033.244	.2894042E+01
	.0100	779.543	-82.615	696.928	.1751998E+01
	.0150	546.198	-77.947	468.251	.1392931E+01
	.0200	386.152	-74.313	311.838	.1228161E+01
	.0250	275.632	-71.448	204.184	.1139724E+01
	.0300	198.761	-69.159	129.602	.1088217E+01
	.0350	144.883	-67.307	77.576	.1056761E+01
	.0400	106.813	-65.788	41.025	.1036977E+01
	.0450	79.682	-64.528	15.154	.1024296E+01
IRR =	.0490	63.763	-63.678	.085	.1017442E+01
	.0500	60.174	-63.470	-3.296	.1016063E+01
	.0550	46.013	-62.572	-16.559	.1010670E+01
	.0600	35.635	-61.801	-26.166	.1007113E+01
	.0650	27.951	-61.133	-33.182	.1004757E+01
	.0700	22.205	-60.549	-38.344	.1003190E+01

FIGURE 3. — The revised red pine problem.

OPTIONS AVAILABLE WITH THE PROGRAM

In addition to the basic components already described, there are several program options available for particular kinds of analyses. These are discussed briefly here, but the details of selecting them are given in the section on "How to Use This Program."

Controlling the Search for Internal Rate of Return

In general, increasing discount rates are applied to the cost, income, and yield data until the IRR is found or until some trial limit is reached. (The search procedure is detailed in the Appendix.) The standard limit is 20 percent, but this can be altered by the analyst. Setting a very low limit will suppress the search; a high limit might result in a long table of discounted costs, incomes, and net worths.

Specifying Discount Rates

In the search for IRR, discounted values will be printed for rates at ½-percent intervals. Further, if an IRR is found, additional discounted values will be printed over a range of another 2½ percent. To insure that present values are calculated for rates of particular interest, those rates can also be specified. The computer prints the discounted values for all specified rates larger than those already printed. In the previous example (fig. 3), had we specified rates of 4¼, 6¾, 8-1/5, and 10 percent, only the latter two would have been printed, for the others would be less than the rates used in the search procedure. However, if we are willing to do without the IRR, we can suppress the search and obtain discounted values for any rates we might specify.

Comparing Rotation Lengths

In addition to evaluating a particular investment under changing price or quality assumptions, we are often interested in the effect of shortening or lengthening the period from establishment to final harvest. In the NCRETURN program, the user can enter an entire volume table as physical yields and determine the potential returns for an array of different rotation lengths.

For example, the pulpwood yields for site index 60 red pine can be entered as physical yields as in figure 4, and rotations increasing by 10-year increments from age 25 to 65 can be specified. Only incomes and costs occurring during the rotation under consideration will be discounted; all others will be ignored.

If, instead of considering only final cuts, we also wanted to utilize thinnings, we would modify the form of our yield input to that shown in figure 5. At each specified age there is a choice between a thinning (intermediate yield) or a clear cut (final yield). In evaluating each rotation length the value of the final yield — that is, the value of the clear cut that is made in the last year of that rotation — and the values of all earlier intermediate harvests are discounted and summed. All other listed final yields and all intermediate yields occurring beyond the end of the rotation are ignored.

Punched Card Output for Further Analysis

In addition to printed output, the user may elect to have the calculated values recorded on punched cards. One card will be punched with all the information, except discounted net worth, contained in each line of the *Table of Discounted Values* and with certain information identifying the problem. This includes the rotation length, a code specifying the price and quality assumptions made, and a limited amount of other data specified by the user. These cards can then serve as a permanent record or, more importantly, as input to some other computer program.

The last line of the descriptive material in figure 3 consists of information to be entered on punched cards: number of trees, site index, and basal area per acre. These values will all be available, for example, as variables to be used in a subsequent regression analysis or can serve as a basis for sorting before ordering the returns to be expected from various alternatives. A detailed description of the output cards is given in a later section.

SCHEDULE OF PHYSICAL YIELDS

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
YIELD	2,	25,	0	,650000E+01	0	0	0	0
YIELD	2,	35,	0	,235000E+02	0	0	0	0
YIELD	2,	45,	0	,420000E+02	0	0	0	0
YIELD	2,	55,	0	,565000E+02	0	0	0	0
YIELD	2,	65,	0	,660000E+02	0	0	0	0

FIGURE 4. — An illustration of entering physical yields to compare rotation lengths.

Sequencing Problems

After analyzing an investment by the NCRETURN program, the user has several options. He can terminate the computer run, he can process a new problem, or he can reprocess the previous problem after changing it in part. Instead of preparing an entire new set of input punched cards, the user can replace one or more of the following types of input without altering the rest of the problem: (1) description, (2) annual payments, (3) single payments, (4) a terminal value, (5) physical yields, (6) price functions, or (7) quality functions.

This option permits him to repeatedly alter, for example, an assumption about the value of his land in the future by preparing only two punched cards for each analysis. He could perform a sensitivity analysis to determine the effect of a particular assumption on an investment's worth.

NORTH CENTRAL FOREST EXPERIMENT STATION (U.S.D.A.)
PROGRAM NCRETURN

PROBLEM NO. 5

COMPARING SEVERAL ROTATION LENGTHS WHEN THINNINGS ARE APPROPRIATE
RED PINE ON SITE INDEX 60 THINNED TO 90 SQUARE FEET BASAL AREA
PRODUCT 2 IS ROUGH CORDS PER ACRE
0 NO JOB CONSTANT

INCOME AND COST SCHEDULE

TYPE	ITEM	AGE	ANNUAL CHANGE	INCOME OR COST	DESCRIPTION
ANNUAL	XF5	0	0	-.500000E+00	ANNUAL COSTS OF TAXES AND GENERAL ADMINISTRATION
SINGLE	YF5	0		-.400000E+02	ESTABLISHMENT COST
SINGLE	ZF5	3.		-.420000E+01	COST OF RELEASE BY AERIAL SPRAYING

SCHEDULE OF PHYSICAL YIELDS

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
YIELD	2,	25.	.160000E+01	.650000E+01	0	0	0	0
YIELD	2,	35.	.102000E+02	.230000E+02	0	0	0	0
YIELD	2,	45.	.116000E+02	.310000E+02	0	0	0	0
YIELD	2,	55.	.123000E+02	.353000E+02	0	0	0	0
YIELD	2,	65.	0	.381000E+02	0	0	0	0

PRICE FUNCTION COEFFICIENTS

PFID	PROD	CONSTANT	FACTOR 1	(FACTOR 1) SQUARED	AGE	(AGE) SQUARED	(AGE) * (FACTOR 1)	JOB CONSTANT	(JOB CON.) SQUARED	(AGE) * (JOB CON.)	DR
PF5	2	.40000E+01	0	0	0	0	0	0	0	0	0

QUALITY FUNCTION COEFFICIENTS

QFID	PROD	CONSTANT	FACTOR 2	(FACTOR 2) SQUARED	FACTOR 3	(FACTOR 2)* (FACTOR 3)	FACTOR 4	(FACTOR 3)* (FACTOR 4)
QF5	2	.10000E+01	0	0	0	0	0	0

VALUE OF PHYSICAL YIELDS (PHYSICAL YIELD * PRICE * QUALITY)

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD
YIELD	2	25.	.640000E+01	.260000E+02
YIELD	2	35.	.408000E+02	.920000E+02
YIELD	2	45.	.464000E+02	.124000E+03
YIELD	2	55.	.492000E+02	.141200E+03
YIELD	2	65.	0	.152400E+03

FIGURE 5. — Comparing rotation lengths when both intermediate and final yields are considered. (Continued on next page.)

.....ROTATION LENGTH = 25 YEARS..... RL NO. 1 OF 5 - PROBLEM NO. 5

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR

INTERNAL RATE OF RETURN IS NON-POSITIVE

.....ROTATION LENGTH = 35 YEARS..... RL NO. 2 OF 5 - PROBLEM NO. 5

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

	DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR
	.0050	82,913	-60,155	22,758	.6243099E+01
	.0100	69,935	-58,781	11,154	.3400368E+01
	.0150	59,047	-57,554	1,492	.2462242E+01
IRR =	.0159	57,378	-57,359	.019	.2356971E+01
	.0200	49,904	-56,457	-6,554	.2000110E+01
	.0250	42,218	-55,473	-13,254	.1728223E+01
	.0300	35,752	-54,587	-18,835	.1551310E+01
	.0350	30,306	-53,788	-23,482	.1428524E+01
	.0400	25,715	-53,066	-27,351	.1339433E+01

.....ROTATION LENGTH = 45 YEARS..... RL NO. 3 OF 5 - PROBLEM NO. 5

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

	DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR
	.0050	138,986	-64,241	74,745	.4974234E+01
	.0100	113,035	-62,124	50,911	.2770505E+01
	.0150	92,093	-60,293	31,801	.2047984E+01
	.0200	75,167	-58,703	16,464	.1695481E+01
	.0250	61,462	-57,317	4,145	.1490700E+01
IRR =	.0270	56,849	-56,824	.025	.1431700E+01
	.0300	50,347	-56,103	-5,756	.1359506E+01
	.0350	41,317	-55,036	-13,719	.1270098E+01
	.0400	33,969	-54,094	-20,125	.1206561E+01
	.0450	27,979	-53,259	-25,280	.1160045E+01
	.0500	23,087	-52,515	-29.428	.1125235E+01

.....ROTATION LENGTH = 55 YEARS..... RL NO. 4 OF 5 - PROBLEM NO. 5

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

	DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR
	.0050	184,312	-68,128	116,183	.4168278E+01
	.0100	145,132	-65,150	79,982	.2372637E+01
	.0150	114,643	-62,652	51,991	.1788678E+01
	.0200	90,850	-60,545	30,305	.1507169E+01
	.0250	72,227	-58,757	13,470	.1346168E+01
	.0300	57,610	-57,231	.379	.1244969E+01
IRR =	.0302	57,223	-57,189	.035	.1241738E+01
	.0350	46,102	-55,920	-9,819	.1177521E+01
	.0400	37,014	-54,788	-17,774	.1130781E+01
	.0450	29,817	-53,804	-23,988	.1097501E+01
	.0500	24,098	-52,945	-28,846	.1073337E+01
	.0550	19,541	-52,189	-32,648	.1055538E+01

.....ROTATION LENGTH = 65 YEARS..... RL NO. 5 OF 5 - PROBLEM NO. 5

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

	DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR
	.0050	224,585	-71,826	152,759	.3611578E+01
	.0100	171,725	-67,890	103,835	.2099667E+01
	.0150	131,980	-64,685	67,294	.1612729E+01
	.0200	101,961	-62,056	39,905	.1381312E+01
	.0250	79,184	-59,882	19,302	.1251385E+01
	.0300	61,821	-58,070	3,751	.1171527E+01
IRR =	.0314	57,595	-57,601	-.006	.1154789E+01
	.0350	48,520	-56,547	-8,027	.1119664E+01
	.0400	38,281	-55,257	-16,976	.1084755E+01
	.0450	30,362	-54,156	-23,794	.1060677E+01
	.0500	24,205	-53,209	-29,004	.1043783E+01
	.0550	19,395	-52,388	-32,993	.1031782E+01

FIGURE 5 Cont'd.

HOW TO USE THIS PROGRAM

The reader has been introduced to some of the types of problems that the NCRETURN program can handle. This section tells the analyst how to prepare his data for processing. Details primarily of interest to a programmer-technician, however, are deferred to the Appendix.

The general computer instructions for this program have been punched on standard 80-column Hollerith cards as FORTRAN statements. (A deck of these "source" cards can be obtained from the Station.) The user must prepare additional cards to define his particular problem. A brief indication of the purpose of these cards may help the reader to understand the instructions detailed below.

The source deck (of approximately 550 cards) prepares the computer to correctly process the user-prepared cards defining his problem. (These may vary greatly in number; only 14 were used for the simple problem illustrated in figure 2.) The computer stores the information on these cards in its memory, works out the problem, and presents the results in a printout. Then any desired modifications are made to the problem by feeding as few as two additional user-prepared cards to the computer.

If these modifications concern price, for example, the computer will erase from its memory the previous price instructions (obtained from the first set of user-prepared cards), store the new price information, and again work out the problem and print out the answers. This process of modifying a problem can be repeated as often as desired.

Organizing Data

Manipulating data to fit the required card formats is a complicated business. As a guide, the input form shown as figure 6 has been prepared. The entries on the form are those used for the illustration shown in figure 3.

Except for the Control card, the form becomes self-explanatory after some preliminary discussion. Note that each type of card is numbered, and that number is entered in the last column. The cards must be sequenced so that, for example, all the No. 4 cards (annual payments) precede the first single-payment (No. 5) card. In addition, the last card of each type must have a minus sign in column 79.[6] While there are 10 different types of input cards available, not all will be required for every problem.

[6] *It is necessary to specify on the Control card only the types of input cards to be used for a particular problem, not how many of each type. The computer checks column 79 of each card: if it is punched with a minus sign, that card is the last of its type. Column 80 is checked to ensure that the card types are properly sequenced.*

Formats of Individual Punched Cards

In the following detailed card descriptions, several conventions are followed. Any columns for which no instructions are provided will be ignored by the computer. Leaving a field blank is equivalent to entering a zero. All dollar values are assumed to be positive (incomes) unless a leading negative sign is punched (costs). All percentages must be expressed as proportions and entered in decimal form. Ages and rotation lengths must be whole numbers.

The code "p.a.p." (print as punched) signifies that the corresponding field will be printed as punched but will neither be used for computations nor stored internally. When the code "d.a.l." (decimal assumed left) is used, the corresponding card field is assumed to have an implicit (unpunched) decimal at the extreme left, so entries must be made at the extreme left. Given "d.a.l.," a negative value can be entered in that field only by punching in consecutive columns a negative sign, a decimal, and the appropriate number (e.g. —.043). When "d.a.l." is not used and no decimal is punched, the card field is assumed to have an implicit decimal at the extreme right. Explicitly punched decimals override the above restrictions.

The reader will find it helpful to refer to figure 6 while reading the following specifications.

0. *Control Card*

Of the 10 types of input cards, the first 4 give the "setting" of a problem. By means of the first, the Control card, the user prepares the computer to accept his problem. The types of input data are specified so that, for example, the computer will correctly interpret $.50 as an annual cost rather than treat it as a terminal value. The choice of options is also made here and, if punched card output is desired, identifying data to be entered on those cards can be specified.

The entry in the first two columns of this card provides general control. If that entry is:

(a) —1: the card prepares the computer to analyze a new problem completely specified by the input cards following the Control card;

(b) +1: the card provides control for modifying the previous problem by replacing, adding and/or deleting certain inputs, and subjecting the altered problem to a new analysis;

(c) zero or blank: the computer run is to be terminated; in addition to preceding every new or modified problem, a Control card must also follow the last problem in a computer run.

NC RETURN — INPUT DATA FORM — SIDE 1 (VALUES)

CONTROL CARD #0

1–2	NPROD 1–9 (5–14)	KDP (17)	TOPIRR (20–24)	PUNCH CARD OUTPUT: JOB CONSTANT (31–38)	DESCRIPTION — CONTENT OPTIONAL (39–62)	79–80
-1	1 1 1 1 1 2	1	.1200	800	TREES SITE65 BA90SQFT	-0

DESCRIPTION CARDS #1 — DESCRIPTION CARDS — CONTENT OPTIONAL (LAST CARD MUST HAVE -1)

1–78	79–80
REVISED RED PINE PROBLEM	1
SITE INDEX 65 THINNED TO 90 SQ. FT. B.A. EVERY 10 YEARS	1
800 TREES AND 148 SQ. FT. B.A. BEFORE THINNING, AGE 25	1
PRODUCT 2 - ROUGH CORDS PER ACRE TO A 3-INCH TOP D.I.B.	1
PRODUCT 3 - THOUSANDS OF BD. FT. PER ACRE, INTL. 1/4-INCH, TO 6-INCH TOP	1
FACTOR 1 - D.B.H. OF TREE OF AVERAGE B.A.	1
FACTOR 2 - TOTAL HEIGHT OF STAND	1
FACTOR 4 - PROPORTION SAWLOG VOLUME THAT IS CULL	-1

ROTATION LENGTHS CARD #2 — ROTATION LENGTHS — ENTERED FROM LEFT TO RIGHT

1–3	79–80
85	-2

DISCOUNT RATES CARD #3 — DISCOUNT RATES — ENTERED FROM LEFT TO RIGHT — DECIMAL ASSUMED AT LEFT

1–4	5–8	9–12	13–16	79–80
.020	.030	.040	.050	-3

ANNUAL PAYMENT CARDS #4

ITEM (1–3)	AGE (6–8)	CHANGE (11–15)	INCOME OR COST (18–28)	DESCRIPTION (LAST CARD MUST HAVE -4) (31–78)	79–80
1	0	0	-.50	ANNUAL COST	4
11	0	0	.20	ANNUAL INCOME	-4

SINGLE PAYMENT CARDS #5

ITEM (1–3)	AGE (6–8)	INCOME OR COST (18–28)	DESCRIPTION (LAST CARD MUST HAVE - 5) (31–78)	79–80
2	0	-40.00	ESTABLISHMENT COST	5
3	3	- 4.80	RELEASE COST	5
4	0	-10.00	LAND PURCHASE	-5

TERMINAL VALUE CARD #6

ITEM (1–3)	INCOME OR COST (18–28)	DESCRIPTION (31–78)	79–80
5	10.00	LAND SALE AT END OF ROTATION	-6

NC-4800-12 (June 1966) U.S. Department of Agriculture — Forest Service — North Central Forest Experiment Station

NCRETURN — INPUT DATA FORM — SIDE 2 (PHYSICAL YIELDS)

CONTROL CARD #0

1–2	NPROD 1–9 (5–14)	KDP (17)	TOPIRR (20–24)	PUNCH CARD OUTPUT: JOB CONSTANT (31–38)	DESCRIPTION — CONTENT OPTIONAL (39–62)	79–80
						0

PHYSICAL YIELD CARDS #7 (LAST CARD MUST HAVE -7)

PROD (4)	AGE (6–8)	INTERMEDIATE YIELD (9–18)	FINAL YIELD (19–28)	FACTOR 1 (29–38)	FACTOR 2 (39–48)	FACTOR 3 (49–58)	FACTOR 4 (59–68)	79–80
2	25	7.4	0	5.8	34.0	0	0	7
2	35	11.8	0	7.6	47.5	0	0	7
2	45	4.3	0	9.7	59.5	0	0	7
3	45	4.91	0	9.7	59.5	0	0	7
3	55	7.81	0	12.2	70.0	0	0	7
3	65	8.36	0	15.0	78.5	0	.01	7
3	75	9.05	0	18.1	85.5	0	.03	7
3	85	0	31.32	21.4	92.0	0	.05	-7

PRICE FUNCTION CARDS #8

PFID (1–3)	PROD (4)	CONSTANT (5–12)	FACTOR 1 (13–20)	$(FACTOR\ 1)^2$ (21–28)	AGE (29–36)	$(AGE)^2$ (37–44)	(FACTOR 1) (AGE) (45–52)	JOB CONSTANT (53–59)	$(JOB\ CONSTANT)^2$ (60–66)	(AGE) (J.C.) (67–73)	dr (74–78)	79–80
PF3	2	-1.00	.50	0	0	0	0	0	0	0	0	8
PF3	3	-30.00	5.00	-.10	0	0	0	0	0	0	0	-8

QUALITY FUNCTION CARDS #9

QFID (1–3)	PROD (4)	CONSTANT (5–12)	FACTOR 2 (13–20)	$(FACTOR\ 2)^2$ (21–28)	FACTOR 3 (29–36)	(FACTOR 2) (FACTOR 3) (37–44)	FACTOR 4 (45–52)	(FACTOR 3) (FACTOR 4) (53–60)	79–80
QF3	2	.30	.02	0	0	0	0	0	9
QF3	3	1.00	0	0	0	0	-1.0	0	-9

FIGURE 6. — Form prepared to assist in punching the revised red pine problem onto input cards.

When a problem is to be analyzed, the precise meaning of the individual entries on this card depends on whether a new problem is being introduced or an earlier problem modified. For a new problem, all data specifying the problem are entered on cards following the Control card. For modifications, however, only cards specifying the changes are entered. Possible entries on the Control card for both situations are detailed in table 1.

When altering a problem, every entry on the Control card results in all cards for a particular type of input being deleted from the schedules of the preceding job and replaced by new input cards. For example, suppose it were necessary to evaluate the same physical yields of one of several products, using two different price functions. The procedure would be to enter the physical yield inputs, complete with a price function for each product, and obtain the desired output. Then insert a Control card with a one entered in column 13. Follow this with the altered price function for the product being reevaluated; then repeat the original price functions for the other products, even though their value will not change. The cardinal rule is that an entry implies *all* of the cards of a given type will be replaced.

If a type of input, say the annuity cards, is not included in the first problem but is to be added for the second, simply enter a one in column 8 and then supply the desired cards. Conversely, if such cards are to be deleted after once occurring, enter a one and supply a single blank card (except columns 79-80 would be punched —4 to meet the sequencing requirement).

1. *Description Cards*

This type of card is optional. The only restrictions on content are that column 80 must always contain a one on all cards and column 79 of the last card must have a minus sign.

2. *Rotation Lengths Card*

This card is mandatory whenever a new problem is introduced but not allowed otherwise. All rotation lengths must be whole numbers and must be entered from left to right.

Columns	*Entry*
1- 3	1st rotation length
4- 6	2nd rotation length
.	.
.	.
.	.
.	.
76-78	26th rotation length
79-80	—2

3. *Discount Rates Card*

This card is available to specify especially desirable discount rates. It can only be used when introducing a new problem. Whatever the specified rates, only those exceeding the largest rate used in searching for the IRR will be used. Rates must be entered starting at the left of the card and they must increase from left to right (d.a.l.).

Columns	*Entry*
1- 4	1st discount rate
5- 8	2nd discount rate
.	.
.	.
.	.
.	.
73-76	19th discount rate
79-80	—3

4. *Annual Payment Cards*

All annuities are assumed to begin at the time of establishment (i.e., age zero). If this is not true, or if noncontinuous changes over time occur, refer to the discussion of entering complex annuities. The last card of this type must have a minus sign in column 79. A maximum of 70 of these cards may be entered.

Columns	*Entry*
1- 3	Item (p.a.p.)
6- 8	Age of last occurrence. If blank or zero, it is assumed the annuity continued for the length of rotation. Only that part occurring during each rotation will be discounted.
11-15	Decimal form of percent annual change in annuity (d.a.l.)
18-28	Payment (income or cost)
31-78	Description (p.a.p.)
80	4

5. *Single Payment Cards*

The age at which payment is made is indicated on the card. The last card of this type must have a minus sign in column 79. A maximum of 70 of these cards may be entered.

Columns	*Entry*
1- 3	Item (p.a.p.)
6- 8	Age of occurrence. If blank or zero, payment was made at time of stand establishment. Payment will be considered only if age is less than rotation length.
18-28	Payment (income or cost)
31-78	Description (p.a.p.)
80	5

6. *Terminal Value Card*

By definition, the terminal value occurs at the end of each rotation. Only one card may be used; none is required.

Columns	*Entry*
1- 3	Item (p.a.p.)
18-28	Terminal value (income or cost)
31-78	Description (p.a.p.)
79-80	—6

Table 1.--Control card entries required to begin a new problem or to alter an old one 1/

Card Columns	To begin a new problem: Entry	Interpretation	To alter an old problem: Entry	Interpretation
1-2	-1	Begin new problem	+1	Alter old problem
5	1	Read description cards	1	Replace description cards
6	1	Read rotation lengths		NE 2/
7	1	Read discount rates		NE 2/
8	1	Read annual payments	1	Replace annual payments
9	1	Read single payments	1	Replace single payments
10	1	Read terminal value	1	Replace terminal value
11	1-9	This number of physical yield products are included	1-9	This number of physical yield products are included
12		NE 3/	1	Replace physical yields
13		NE 3/	1	Replace price functions
14		NE 3/	1	Replace quality functions
17	1	Punched card output		NE 2/
20-24		Control of IRR search		Control of IRR search
	-.1	IRR not to be calculated	-.1	IRR not to be calculated
	0	Search limit (TOPIRR) set at 0.20	0	No change in search limit
	> 0	Search limit (TOPIRR) as specified	> 0	Search limit as specified
31-38		Job constant		Job constant
	0	Set = 0	0	No change in Job Constant <u>or</u> punched card description
	≠0	Set as specified	≠0	Set Job Constant <u>and</u> punch card description as specified
39-62		Set punch card description as specified		See above
80	0	Mandatory zero	0	Mandatory zero

1/ Entry of a zero is equivalent to leaving that column blank. For new problems, this means that a particular kind of input is not relevant. For altered problems, it means that this kind of input is not to be changed.

2/ No entry is permitted. Changes in rotation lengths, discount rates, and the choice of the punched card option can be made only by entering a complete new problem.

3/ No entry is necessary. As in figure 6, specifying some number of physical products in column 11 (in this case, 2) implies that the same number of price and quality function cards, as well as some physical yield cards, will be entered. When altering a problem, an entry in column 11 is interpreted in the same manner; then, however, even if no entry is made (implying no change in the <u>number</u> of products), it is permissible to change any of these cards.

7. *Physical Yield Cards*

Physical yields are entered with their associated *Factors,* which are available for use with the price and quality functions. The final yield will be used if the age of occurrence (columns 6-8) is the same as the rotation length, and the intermediate yield if the age is less than the rotation length; the entries on the card will not be used if the age exceeds the rotation length. The last card of this type must have a minus sign in column 79. A maximum of 270 of these cards may be entered.

Columns	*Entry*
4	Product code (positive integer)
6- 8	Age of occurrence
9-18	Intermediate yield
19-28	Final yield
29-38	Factor 1
39-48	Factor 2
49-58	Factor 3
59-68	Factor 4
80	7

There must be one price and one quality function input card for each product.

8. *Price Function Cards*

The coefficients of all variables available in the price function are entered here. A constant annual change in price over time can be specified. Entering a one in column 12 and leaving columns 13-79 blank neutralizes the price function. There must be one card for each physical yield product.

Columns	*Entry*
1- 3	Price function identification (PFID)
4	Product code (positive integer)
5-12	Constant for price function
13-20	Coefficient for factor 1
21-28	Coefficient for (factor 1)^2
29-36	Coefficient for age
37-44	Coefficient for (age)^2
45-52	Coefficient for (age) x (factor 1)
53-59	Coefficient for job constant
60-66	Coefficient for (job constant)^2
67-73	Coefficient for (age) x (job constant)
74-78	Decimal form of % annual change in prices (d.a.l.)
80	8

Since column 11 on the Control card implies the number of price and quality functions supplied, there is no requirement that those last cards have minus signs. However, it is a recommended practice.

9. *Quality Function Cards*

The coefficients of all variables available in the quality function are entered here. Entering a one in column 12 neutralizes this function. There must be one card for each physical yield product.

Columns	*Entry*
1- 3	Quality function identification (QFID)
4	Product code (positive integer)
5-12	Constant for quality function
13-20	Coefficient for factor 2
21-28	Coefficient for (factor 2)^2
29-36	Coefficient for factor 3
37-44	Coefficient for (factor 2) x (factor 3)
45-52	Coefficient for factor 4
53-60	Coefficient for (factor 3) x (factor 4)
80	9

The preceding card descriptions are summarized on the front and back of the last page in the report (fig. 14). By removing it and perhaps putting it in a transparent envelope, the reader will have available an abbreviated description of all the input cards. While neither this aid nor the specially prepared input form (fig. 6) eliminates the need to thoroughly understand the detailed card specifications, they will relieve much of the effort required in card preparation.

DESCRIPTION OF PROGRAM OUTPUT

Standard Printout

When physical yields are used as inputs, two tables will result: one listing the input in its original form, including the yield factors, and a second table listing only the values obtained by combining the physical yields with the appropriate price and quality functions. If, in altering a problem, physical yields are retained and not explicitly re-entered, the first table of "raw" data described above will not be printed. Similarly, the content of description cards and the optional descriptions of annual and one-time payments will be printed as input only with those problems for which they have been explicitly entered. All other input information printed for the first problem will be repeated. (See the description of the Control card for full details for sequencing and altering problems.)

Printed program output will normally consist of a *Table of Discounted Values.* This contains, for each discount rate used, the resulting discounted income, cost, and net worth plus an adjustment factor for infinite series of rotations. Discount rates begin at one-half of one percent and are printed at one-half percent intervals. When the internal rate of return is found — that is, when the discounted net worth changes from positive to negative — it is printed and is followed by discounted values based on five more interest rates at one-half percent intervals. At that point, if the user has specified any discount rates which exceed the largest rate already printed, the discounted values resulting from those rates are also printed.

If the internal rate of return is not found before the upper search limit specified by the user is reached, an appropriate message will be printed. Any specified discount rates which exceed the search limit will then be utilized and the printout will be completed when those rates have been exhausted.

Program Diagnostics

Several other types of messages or diagnostics may be encountered. Each of these is listed below.[7]

Message	*Reason for Occurrence*
Output on Punched Cards (311)	Information only
Problem has no Annual or Single Payments (316)	Information only
Problem has no Physical Yield (604)	Information only
No Income or Cost Input to Program (1109)	Information: these occur in output table. Explains reason why IRR is not found. Next step is to utilize user-specified discount rates.
No Income Input to Program (1113)	
Internal Rate of Return is Non-Positive (1122)	
Positive IRR Exists but Returns Precede Costs (1131)	
IRR Exceeds Specified Maximum Search Limit of TOPIRR = x.xxxxxx (1320)	
Normal End of Program NCRETURN (9999)	Terminates computer run after last problem.
Stop 9999 (9999)	
Stop 990x (990x)	Terminates run if sequence check finds cards are out of order. x is the entry in column 80 of the expected type of card. The checks are contained in the following routines (see Appendix for details of subprograms):
Stop 9900 (Control)	In main program
Stop 9901 (Description)	In main program
Stop 9902 (Rotations)	In main program
Stop 9903 (Rates)	In main program
Stop 9904 (Annual)	In RDADPT subprogram
Stop 9905 (Single)	In RDPDPT subprogram
Stop 9906 (Terminal)	In RDTVPT subprogram
Stop 9907 (Physical)	In RDPHYS subprogram
Stop 9908 (Price)	In RDPFN subprogram
Stop 9909 (Quality)	In RDQFN subprogram

[7] *The FORTRAN statement numbers in parentheses following the diagnostics are provided to assist the programmer-technician in interpreting the problem source deck. Those cards are listed in the Appendix.*

Finally, pages of computer output are ordered by an internally controlled system. Problems are sequenced within a computer run, the problem number being advanced by each Control card. Each rotation length is also numbered within each problem. The result is pagings such as

"RL NO. 2 of 4 — Problem No. 3"

Punched Card Output

Punched cards will supplement the printed output if the entry in column 17 of the Control card is a one. One card will be punched for each discount rate printed in the *Table of Discounted Values* as specified below.

Columns	*Entry*
1- 8	Job Constant
9-32	Columns 39-62 of Control card
33-35	PFID (as punched on *last* price function card in problem)
36-38	QFID (as punched on *last* quality function card in problem)
39-41	Rotation length
42-47	Internal rate of return or other discount rate (punched in decimal form as x.xxxx)
48-56	Sum of discounted incomes (punched xxxxxx.xx)
57-65	Sum of discounted costs (punched —xxxxx.xx)

Columns	*Entry*
66	"1" if terminal value included; zero, otherwise
67-79	Adjustment factor for infinite rotations (punched .xxxxxxxE±xx)
80	"1" if this card contains an internal rate of return; "2", otherwise

Figure 7 pictures the punched card output from the revised red pine illustration of figures 3 and 6. Notice that the first 32 columns on all the cards are identical. The content was specified on the Control card as shown in figure 6. Even though it was not used in a price function, a Job Constant was specified and appears on these cards. It was set equal to the number of trees per acre and, with the site index and basal area, provides a set of variables that is available for use in further computer analysis. In addition, the cards are identified more fully than if these data were missing.

As stated previously, the underlying price and quality assumptions are also identified through the *PFID* and *QFID* codes. They are especially valuable in identifying cards when a series of price-quality assumptions are applied to a set of data. The reader is cautioned to note that these price-quality assumptions are identified as *sets.* If more than one product is considered, those *PFID* and *QFID* codes corresponding to the last entered price and quality functions are the ones punched onto the cards.

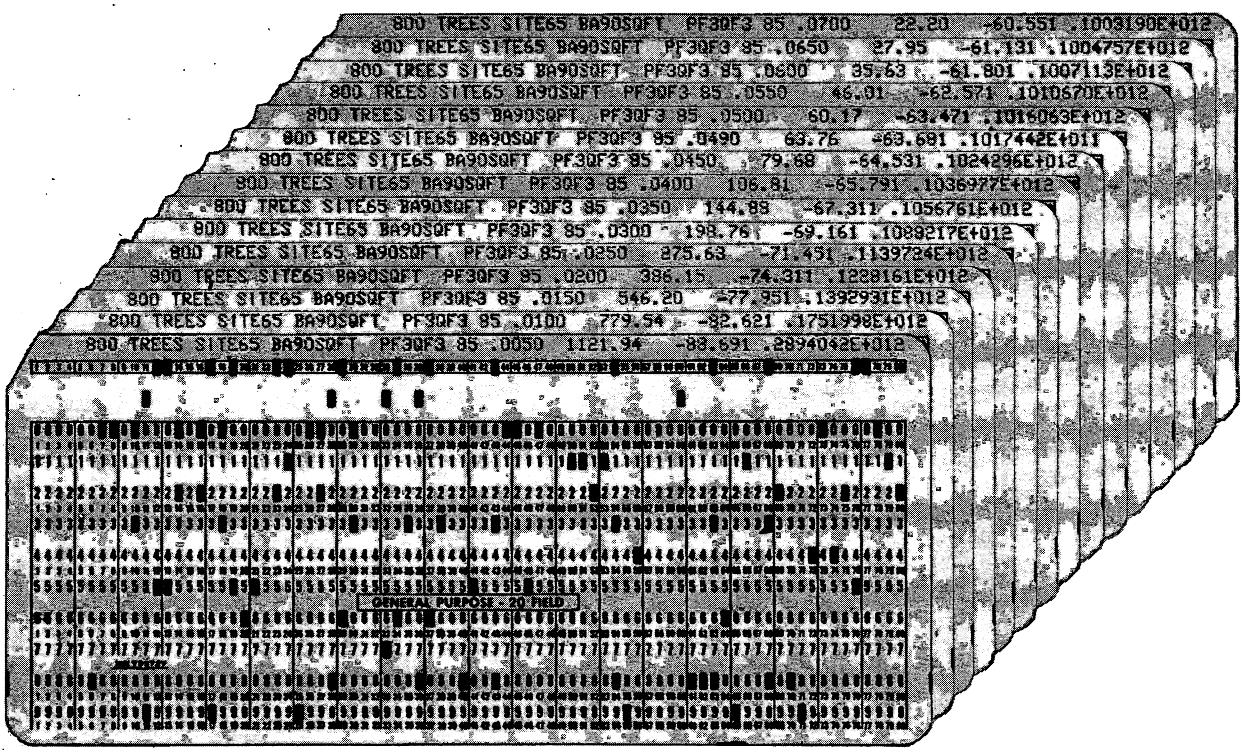


FIGURE 7. — Punched card output from the revised red pine problem.

USE OF THE PROGRAM FOR SPECIAL PROBLEMS

It was noted at the beginning of this paper that the program can be applied to problems other than those suggested by the illustrations. For example, the intermediate and final yields listed in the *Schedule of Physical Yields* could be in either physical or value units. Price and quality are arbitrary words for two mathematical functions that are to be multiplied by these yields, and these functions can be redefined in any appropriate way. Price factors can be entered in the quality function, or variables affecting quality in the price function; to get a more complex function, price or quality factors can be entered in both functions.

The ultimate test of a computer program is to ask "will it solve my problem?" Applications that may not be readily apparent are discussed below. Other examples of flexibility and specific questions will probably occur to the user as he works with the program. The authors would be pleased to exchange information concerning applications with any interested persons.

Transforming Physical Yields

Ordinarily, the physical yields entered as input are in cords, board feet, lineal feet of piling, or some other merchantable unit. These physical yields are multiplied by the price and quality functions to obtain values. We can also enter yields in a more basic unit of measure, such as cubic feet, and let the computer convert it to merchantable volume in the evaluation process. For example, we might allow .0097 cords per cubic foot as the converting factor by entering it into the quality function. Since physical yields are multiplied by both the price and quality functions, the effect is the same as if we had measured wood in cords and neutralized the quality function by assigning it a value of one.

Figure 8 is an example of using gross volume yields as input when two different products — measured in cords and board feet — are to be extracted from harvests measured in cubic feet. In addition to entering the intermediate and final yields in cubic feet into the *Schedule of Physical Yields,* we enter the cubic feet-to-cords and cubic feet-to-board feet conversion factors as *Factor 2* and *Factor 4*, respectively, for each entry in that schedule. For example, a cubic foot of wood harvested at age 25 would be expected to yield .0091 cord; a cubic foot at age 45 would contain 3.53 board feet in addition to .0031 cord in tops and small trees.

In order to have the proper linkage between the gross yields, the conversion factors, and the price per merchantable unit, the price and quality functions must be reinterpreted. Since *Factor 2* and *Factor 4* are variables utilized in the quality function, we introduce our unit prices as *Quality Function Coefficients*. That is, the coefficient for *Factor 2* (the cubic feet-to-cords ratio) is the price per cord, \$3.50; the coefficient for *Factor 4* is \$.025, the price per board foot. The final step is to give the price function a constant value of one so it can be ignored.

Having made these entries into the program, we generate the *Value of Physical Yields* table from the relationship

$$V = Y \times P \times Q$$

In this example, we can substitute

$$\begin{aligned} V &= [Y] \times [1] \times [(\text{Coeff. } F_2)\ (\text{Factor } 2) + (\text{Coeff. } F_4)\ (\text{Factor } 4)] \\ &= [\text{cu. ft.}] \times [(\text{price/cd.})\ (\text{cds/cu. ft.}) + (\text{price/bd. ft.})\ (\text{bd. ft./cu. ft.})] \\ &= (\text{cu. ft.})\ (\text{cds./cu. ft.})\ (\text{price/cd.}) + (\text{cu. ft.})\ (\text{bd. ft./cu. ft.})\ (\text{price/bd. ft.}) \end{aligned}$$

The future values of the final yields at ages 55 and 85 would be

$$\begin{aligned} V_{55} &= (4040)\ (.0004)\ (\$3.50) + (4040)\ (4.97)\ (\$.025) \\ &= \$507.63 \\ V_{85} &= 0 + (4760)\ (6.58)\ (\$.025) \\ &= \$783.02 \end{aligned}$$

An even more complex example is given by figure 9, which illustrates the same type of problem as the preceding one except that the physical yield data are entered in a still more elementary form. Instead of entering cubic feet, we enter the field measurements of basal area and height in the *Schedule of Physical Yields,* letting the computer do the work of putting them together to calculate cubic-foot volume from the following relationship:

Cubic feet = (.4085) (basal area) (height)

The input data are summarized below:

Printed heading	*Entry*
Schedule of Physical Yields	
Yield	basal area in square feet/acre
Factor 2	cords/cu. ft. (conversion factor)
Factor 3	height in feet
Factor 4	bd. ft./cu. ft. (conversion factor)
Price Function	
Constant	.4085 (form factor to obtain cu. ft. from the product of basal area and height)

NORTH CENTRAL FOREST EXPERIMENT STATION (U.S.D.A.)
PROGRAM NCRETURN PROBLEM NO. 8

AN EXAMPLE OF TRANSFORMING PHYSICAL YIELDS FROM CUBIC FOOT VOLUME PER ACRE
TO CORDS AND BOARD FEET PER ACRE, PHYSICAL YIELDS SHOWN ARE IN CU.FT.
FACTOR 2 IS CORDS PER CUBIC FOOT
FACTOR 4 IS BOARD FEET PER CUBIC FOOT
STUMPAGE PRICES PER CORD AND PER BOARD FOOT ARE GIVEN AS COEFFICIENTS OF
FACTORS 2 AND 4 RESPECTIVELY IN THE QUALITY FUNCTION CARD
0

INCOME AND COST SCHEDULE

TYPE	ITEM	AGE	ANNUAL CHANGE	INCOME OR COST	DESCRIPTION
ANNUAL	1	0	0	=.500000E+00	ANNUAL COST
SINGLE	2	0		=.500000E+02	ESTABLISHMENT COST
SINGLE	3	3.		=.420000E+01	RELEASE COST
SINGLE	4	0		=.100000E+02	LAND PURCHASE
TERMINAL	5.			.100000E+02	LAND VALUE AT END OF THE ROTATION

SCHEDULE OF PHYSICAL YIELDS

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
YIELD	1.	25.	.810000E+03	.206000E+04	0	.910000E=02	0	0
YIELD	1.	35.	.122000E+04	.297000E+04	0	.970000E=02	0	0
YIELD	1.	45.	.139000E+04	.358000E+04	0	.310000E=02	0	.393000E+01
YIELD	1.	55.	.147000E+04	.404000E+04	0	.400000E=03	0	.497000E+01
YIELD	1.	65.	.148000E+04	.436000E+04	0	0	0	.565000E+01
YIELD	1.	75.	.145000E+04	.459000E+04	0	0	0	.624000E+01
YIELD	1.	85.	.138000E+04	.476000E+04	0	0	0	.658000E+01
YIELD	1.	95.	0	.489000E+04	0	0	0	.679000E+01

PRICE FUNCTION COEFFICIENTS

PFID	PROD	CONSTANT	FACTOR 1	(FACTOR 1) SQUARED	AGE	(AGE) SQUARED	(AGE) * (FACTOR 1)	JOB CONSTANT	(JOB CON.) SQUARED	(AGE) * (JOB CON.)	DR
10	1	.10000E+01	0	0	0	0	0	0	0	0	0

QUALITY FUNCTION COEFFICIENTS

QFID	PROD	CONSTANT	FACTOR 2	(FACTOR 2) SQUARED	FACTOR 3	(FACTOR 2)* (FACTOR 3)	FACTOR 4	(FACTOR 3)* (FACTOR 4)
F02	1	0	.35000E+01	0	0	0	.25000E-01	0

VALUE OF PHYSICAL YIELDS (PHYSICAL YIELD * PRICE * QUALITY)

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD
YIELD	1	25.	.257985E+02	.656110E+02
YIELD	1	35.	.414190E+02	.100831E+03
YIELD	1	45.	.137749E+03	.354778E+03
YIELD	1	55.	.184705E+03	.507626E+03
YIELD	1	65.	.209050E+03	.615850E+03
YIELD	1	75.	.226200E+03	.716040E+03
YIELD	1	85.	.227010E+03	.783020E+03
YIELD	1	95.	0	.830078E+03

.....ROTATION LENGTH = 65 YEARS..... RL NO. 1 OF 1 = PROBLEM NO. 8

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

	DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR
	.0050	760.569	=91.826	668.742	.3611578E+01
	.0100	572.020	=87.890	484.131	.2099667E+01
	.0150	432.089	=84.685	347.404	.1612729E+01
	.0200	327.860	=82.056	245.804	.1381312E+01
	.0250	249.933	=79.882	170.051	.1251385E+01
	.0300	191.444	=78.070	113.374	.1171527E+01
	.0350	147.369	=76.547	70.822	.1119664E+01
	.0400	114.018	=75.257	38.761	.1084755E+01
	.0450	88.674	=74.156	14.518	.1060677E+01
IRR.=	.0488	73.333	=73.414	=.081	.1047321E+01
	.0500	69.331	=73.209	-3.878	.1043783E+01
	.0550	54.500	=72.388	=17.887	.1031782E+01
	.0600	43.077	=71.671	=28.593	.1023178E+01
	.0650	34.237	=71.041	=36.804	.1016966E+01
	.0700	27.363	=70.483	=43.121	.1012458E+01

FIGURE 8. — Transforming physical yields — the conversion of cubic feet to cords and board feet before evaluation.

NORTH CENTRAL FOREST EXPERIMENT STATION (U.S.D.A.)
PROGRAM NCRETURN

PROBLEM NO. 9

AN EXAMPLE OF TRANSFORMING PHYSICAL YIELDS LISTED AS BASAL AREA IN SQ.FT. PER ACRE TO CORDS AND BOARD FEET PER ACRE.
FACTOR 2- CORDS PER CUBIC FOOT , FACTOR 3- TOTAL HEIGHT OF STAND,
FACTOR 4- BOARD FEET PER CUBIC FOOT,
STUMPAGE PRICES ARE GIVEN AS QUALITY FUNCTION COEFFICIENTS -
FACTOR(2)(3) = PRICE PER CORD , FACTOR(3)(4) - PRICE PER BOARD FOOT.
0

INCOME AND COST SCHEDULE

TYPE	ITEM	AGE	ANNUAL CHANGE	INCOME OR COST	DESCRIPTION
ANNUAL	1	.0	0	=.500000E+00	ANNUAL COST
SINGLE	2	0		=.500000E+02	ESTABLISHMENT COST
SINGLE	3	3.		=.420000E+01	RELEASE COST
SINGLE	4	0		=.100000E+02	LAND PURCHASE
TERMINAL	5			.100000E+02	LAND SALE AT THE END OF THE ROTATION

SCHEDULE OF PHYSICAL YIELDS

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
YIELD	1.	25.	.580000E+02	.148000E+03	0	.910000E=02	.340000E+02	0
YIELD	1.	35.	.631000E+02	.153100E+03	0	.970000E=02	.475000E+02	0
YIELD	1.	45.	.571000E+02	.147100E+03	0	.310000E=02	.595000E+02	.353000E+01
YIELD	1.	55.	.513000E+02	.141300E+03	0	.400000E=03	.700000E+02	.497000E+01
YIELD	1.	65.	.461000E+02	.136100E+03	0	0	.785000E+02	.565000E+01
YIELD	1.	75.	.414000E+02	.131400E+03	0	0	.855000E+02	.624000E+01
YIELD	1.	85.	.367000E+02	.126700E+03	0	0	.920000E+02	.658000E+01
YIELD	1.	95.	.328000E+02	.122800E+03	0	0	.975000E+02	.679000E+01

PRICE FUNCTION COEFFICIENTS

PFID	PROD	CONSTANT	FACTOR 1	(FACTOR 1) SQUARED	AGE	(AGE) SQUARED	(AGE) * (FACTOR 1)	JOB CONSTANT	(JOB CON.) SQUARED	(AGE) * (JOB CON.)	DR
F03	1	.40850E+00	0	0	0	0	0	0	0	0	0

QUALITY FUNCTION COEFFICIENTS

QFID	PROD	CONSTANT	FACTOR 2	(FACTOR 2) SQUARED	FACTOR 3	(FACTOR 2)* (FACTOR 3)	FACTOR 4	(FACTOR 3)* (FACTOR 4)
F04	1	0	0	0	0	.35000E+01	0	.25000E=01

VALUE OF PHYSICAL YIELDS (PHYSICAL YIELD * PRICE * QUALITY)

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD
YIELD	1	25.	.256571E+02	.654700E+02
YIELD	1	35.	.415676E+02	.100856E+03
YIELD	1	45.	.137537E+03	.354320E+03
YIELD	1	55.	.184319E+03	.507685E+03
YIELD	1	65.	.208810E+03	.616465E+03
YIELD	1	75.	.225571E+03	.715942E+03
YIELD	1	85.	.226888E+03	.783290E+03
YIELD	1	95.	.221759E+03	.830242E+03

.....ROTATION LENGTH = 65 YEARS.....

RL NO. 1 OF 1 - PROBLEM NO. 9

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

	DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR
	.0050	760.550	=91.826	668.724	.3611578E+01
	.0100	571.978	=87.890	484.088	.2099667E+01
	.0150	432.034	=84.685	347.349	.1612729E+01
	.0200	327.801	=82.056	245.745	.1381312E+01
	.0250	249.874	=79.882	169.991	.1251385E+01
	.0300	191.387	=78.070	113.317	.1171527E+01
	.0350	147.316	=76.547	70.769	.1119664E+01
	.0400	113.969	=75.257	38.712	.1084755E+01
	.0450	88.630	=74.156	14.474	.1060677E+01
IRR =	.0488	73.293	=73.414	=.122	.1047321E+01
	.0500	69.292	=73.209	-3.917	.1043783E+01
	.0550	54.466	=72.388	=17.922	.1031782E+01
	.0600	43.047	=71.671	=28.624	.1023178E+01
	.0650	34.210	=71.041	=36.831	.1016966E+01
	.0700	27.339	=70.483	=43.145	.1012458E+01
	.0800	17.752	=69.542	=51.790	.1006767E+01
	.0900	11.782	=68.778	=56.997	.1003706E+01
	.1000	7.987	=68.145	=60.159	.1002043E+01

FIGURE 9. — Transforming physical yields — the conversion of basal area to cords and board feet before evaluation.

Printed Heading	*Entry*
Quality Function	
Coeff. $F_2 F_3$	\$3.50 (price/cord)
Coeff. $F_3 F_4$	\$ .025 (price/bd. ft.)

When calculating the value of any physical yield entry in this example, we can write:

$$V = [Y] \times [P] \times [(\text{Coeff. } F_2F_3)(\text{Factor 2} \times \text{Factor 3}) + (\text{Coeff. } F_3F_4)(\text{Factor 3} \times \text{Factor 4})]$$

$$V = [\text{basal area}] \times [.4085] \times [(\text{price/cd.})(\text{cds./cu. ft.})(\text{height}) + (\text{price/bd. ft.})(\text{bd. ft./cu. ft.})(\text{height})]$$

Combining and rearranging terms illustrates how value yields are derived from these entries:

$$V = (.4085)(\text{basal area})(\text{height})(\text{cds./cu. ft.})(\text{price/cd.}) + (.4085)(\text{basal area})(\text{height})(\text{bd. ft./cu. ft.})(\text{price/bd. ft.})$$

$$V = (\text{cu. ft.})(\text{cds./cu. ft.})(\text{price/cd.}) + (\text{cu. ft.})(\text{bd. ft./cu. ft.})(\text{price/bd. ft.})$$

The cubic-foot volume in a final harvest at age 25 would be:

$$\text{Cu. ft.} = (.4085)(148)(34.0) = 2056.$$

Rounded to the nearest 10 cubic feet, this is the same volume shown in figure 8 of the *Schedule of Physical Yields*.

We hope that these illustrations will be enough to suggest other possibilities to the reader. Problems encountered in practical situations may be even more complex than the examples shown here in that several products may be involved and prices may change frequently.

Discounting Physical Yields

In some instances it may be desirable to calculate discounted physical yields rather than the discounted values for specific incomes and costs.[8] Using this approach, only one product can be entered in each problem. If neutralizing constants of one are entered in both the price and quality functions and no other incomes or costs are considered, the sum of the discounted yields can be read directly from the printout in the discounted income column. In addition, since the intermediate output printed in the *Value of Physical Yields* is the product of yields and the two functions, it can be used as a merchantable volume yield table if the functions are used to convert field measurements to measures of marketable products. A series of such tables could be generated, each in terms of a different potential product, if the converting functions were altered on successive runs.

Costs in Physical Terms

The program was initially designed to handle incomes in terms of either dollars or physical volumes, and costs in dollars. But if we wish, we can also enter costs in physical units.

For a stated age we might enter units such as the number of man-hours, tons of effluent, or trees planted per acre. With each type of physical unit we would have a price function with a negative price unit (wage per hour, charge per ton, cost per tree). For example, we could use man-hours of labor and, by varying the price function, test the effect of different levels of wage rates on investment return.

If the above suggestion is followed, there will be negative entries in the *Value of Physical Yields* table. These values will be discounted as costs in the usual manner. Incomes and costs, then, can both be entered in the *Physical Yield Schedule* for the same problem; they will be discounted and printed separately in the *Table of Discounted Values.*

Complex Annuities

It has been seen that annuities beginning at age zero and, perhaps, changing at a constant rate over time can be handled by preparing single input cards. By combining entries we can also consider annuities which begin after establishment and change at a discontinuous rate over time. If an annual cost is to begin after age zero, it is entered in the normal fashion and an offsetting annual income (on a second input card) is entered as running from age zero to the beginning of the cost.

To cite an example, suppose that in administering a private hunting preserve, we expect a \$.10 per acre annual administrative cost, a \$.20 per acre annual land tax after 10 years, and a \$.05 per acre annual road maintenance expense after 30 years. These expenses could be entered into the program as shown in figures 10 and 11.

When Biological and Investment Ages Differ

In the examples given so far this program has been used to evaluate investments lasting an entire rotation. Although many of the terms used in the program were set up with this specific problem in mind, the program is by no means limited to such problems. If it is used in other ways, however, age must be redefined.

[8] *Lundgren; see footnote 5.*

The term "age" required with many inputs is not necessarily the biological age of a stand of timber but is the age of the investment — that is, the number of years from the start of the investment period. Likewise, the term "rotation length" is actually the length of the investment period in years. A common example utilizing these definitions is given by a pruning analysis.

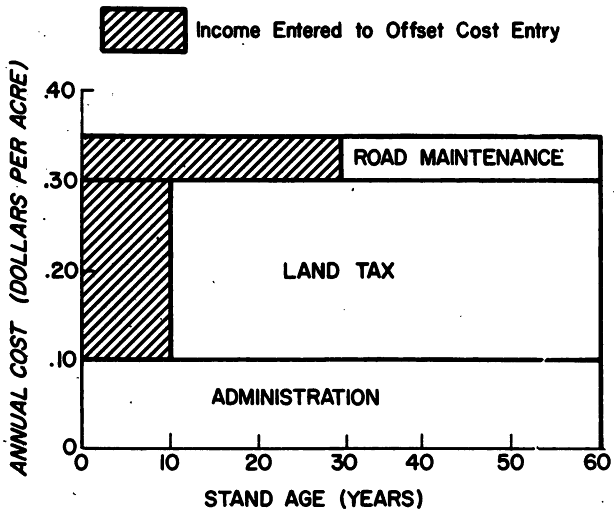


FIGURE 10. — The building-block approach to handling annuities beginning after age zero.

A 25-year-old stand of red pine is to be pruned for saw log production. In this case, the investment period starts at the time of pruning, so the investment age entered as input is zero for this cost. The volumes of clear lumber expected at various times after pruning — years from now — are entered as physical yields (fig. 12). The expected price increase of $20 per thousand board feet of clear lumber resulting from pruning is entered as the price. The output shows the IRR and the discounted incomes, costs, and net worth at the time of pruning for this pruning investment for a rotation length of 60 years; but remember that the rotation length here is defined as the length of the investment period and is not the same as the age of the trees. Thus, the stand age is actually 85 years.

Although the examples given in this paper are of even-aged stands, the user of the NCRETURN program is not restricted to timber investments with a final clear-cut to mark the end of the investment period. It can be used to evaluate investments in stands managed under the selection system, where the stand is never clear-cut. Here, the rotation age is interpreted as the length of the investment period, which may be one or several cutting cycles.

When redefining age (or any other term) for evaluating "special" investments, it is good practice to explicitly define the altered terms in the descriptive material at the top of the printout.

INCOME AND COST SCHEDULE

TYPE	ITEM	AGE	ANNUAL CHANGE	INCOME OR COST	DESCRIPTION
ANNUAL	16	0	0	-.100000E+00	ANNUAL ADMINISTRATION EXPENSE,
ANNUAL	17	0	0	-.200000E+00	ANNUAL LAND TAX FROM AGE 10 ON,
ANNUAL	X17	10.	0	.200000E+00	ASSUMED INCOME TO CANCEL TAX FOR FIRST 10 YEARS,
ANNUAL	18	0	0	-.500000E-01	ANNUAL ROAD MAINTENANCE EXPENSE FROM AGE 30 ON,
ANNUAL	X18	30.	0	.500000E-01	INCOME TO CANCEL ROAD EXPENSE FOR FIRST 30 YRS,

FIGURE 11. — Entering annuities beginning after age zero into the NCRETURN program.

NORTH CENTRAL FOREST EXPERIMENT STATION (U.S.D.A.)
PROGRAM NCRETURN
PROBLEM NO. 12

PRUNING RED PINE - AN EXAMPLE WHERE BIOLOGICAL AND INVESTMENT AGES DIFFER
AT STAND AGE 25, 120 TREES PRUNED TO 17 FEET
TERM AGE BELOW IS NUMBER OF YEARS FROM INVESTMENT IN PRUNING
PRODUCT 9 - RESULTING CLEAR LUMBER IN THOUSANDS OF BD.FT.
PRICE IS VALUE ADDED BY PRUNING PER THOUSAND BOARD FEET
0

INCOME AND COST SCHEDULE

TYPE	ITEM	AGE	ANNUAL CHANGE	INCOME OR COST	DESCRIPTION
SINGLE	TU1	0		-.360000E+02	COST PER ACRE OF PRUNING AT $.30 PER TREE

SCHEDULE OF PHYSICAL YIELDS

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
YIELD	9.	40.	.259000E+01	0	0	0	0	0
YIELD	9.	50.	.336000E+01	0	0	0	0	0
YIELD	9.	60.	0	.135000E+02	0	0	0	0

PRICE FUNCTION COEFFICIENTS

PFID	PROD	CONSTANT	FACTOR 1	(FACTOR 1) SQUARED	AGE	(AGE) SQUARED	(AGE) * (FACTOR 1)	JOB CONSTANT	(JOB CON.) SQUARED	(AGE) * (JOB CON.)	DR
200	9	.20000E+02	0	0	0	0	0	0	0	0	0

QUALITY FUNCTION COEFFICIENTS

QFID	PROD	CONSTANT	FACTOR 2	(FACTOR 2) SQUARED	FACTOR 3	(FACTOR 2)* (FACTOR 3)	FACTOR 4	(FACTOR 3)* (FACTOR 4)
10	9	.10000E+01	0	0	0	0	0	0

VALUE OF PHYSICAL YIELDS (PHYSICAL YIELD * PRICE * QUALITY)

TYPE	PRODUCT	AGE	INTERMEDIATE YIELD	FINAL YIELD
YIELD	9	40.	.518000E+02	0
YIELD	9	50.	.672000E+02	0
YIELD	9	60.	0	.270000E+03

.....ROTATION LENGTH = 60 YEARS.....
RL NO. 1 OF 1 - PROBLEM NO. 12

TABLE OF DISCOUNTED VALUES (IN DOLLARS)

	DISCOUNT RATE	DISCOUNTED INCOME	DISCOUNTED COSTS	DISCOUNTED NET WORTH	INFINITE ROTATIONS ADJUSTMENT FACTOR
	.0050	294.970	-36.000	258.970	.3866560E+01
	.0100	224.273	-36.000	188.273	.2224445E+01
	.0150	170.986	-36.000	134.986	.1692895E+01
	.0200	130.718	-36.000	94.718	.1438398E+01
	.0250	100.210	-36.000	64.210	.1294136E+01
	.0300	77.036	-36.000	41.036	.1204432E+01
	.0350	59.388	-36.000	23.388	.1145389E+01
	.0400	45.912	-36.000	9.912	.1105046E+01
IRR =	.0448	36.047	-36.000	.047	.1077717E+01
	.0450	35.594	-36.000	-.406	.1076761E+01
	.0500	27.673	-36.000	-8.327	.1056564E+01
	.0550	21.575	-36.000	-14.425	.1041947E+01
	.0600	16.869	-36.000	-19.131	.1031262E+01
	.0650	13.227	-36.000	-22.773	.1023392E+01

FIGURE 12. — An example of differing biological and investment ages.

A FINAL WORD

Throughout the paper it has been stressed that the NCRETURN program will handle a wide variety of problems. However, the analyst must still decide whether it will answer his questions. In essence, the program produces rates of return and discounted costs, incomes, and net worths for specified investments. If these would be helpful, the effort required to understand and use the program might be worthwhile. Once the user becomes thoroughly familiar with the program, he will find that it is simple and inexpensive to use. For example, the total direct cost of preparing the input data cards and processing all of the problems given as examples in this paper on a CDC 1604 computer was less than $10.

If the program looks promising, the user must organize his data so that the cards can be punched. For this purpose, special input forms like that in figure 6 can be obtained in reasonable quantities from the Station. After becoming acquainted with the form, speed in entering the data for most problems will be limited only by how fast the user can write.

Finally, it is necessary to get the program into operation on a particular computer. Because computers vary a great deal, only rather general guides can be given. A computer of moderate capacity is required. Although the program was designed for a CDC 1604, with some modification it can be run on an IBM 7090. Since some programming changes will be required, a competent computer programmer is essential. Copies of the FORTRAN source deck and input cards for the illustrations printed in this paper are available to assist in debugging the converted program.

APPENDIX

This section has some material on calculation techniques and contains the program documentation. The latter material especially is primarily of interest to the computer programmer-technician.

Calculating Techniques

Discounting Formulas

The program was explicitly designed to discount all costs and incomes to some common point in time. The procedure is found in the program listing under subroutine *Compute*. For a given rotation, only those payments occurring during the rotation are considered. The formulas used are given below after the definition of terms.

n = rotation length in years

a = age of occurrence given on the input card (or the last age of occurrence of an annuity)

m = either n or a, whichever is smaller

V = annual income or cost

V_a = single income or cost at age a

V_o = discounted value of annual or single incomes or costs

FYV_a = final yield value at age a

IYV_a = intermediate yield value at age a

p = time discount rate (in decimal form)

r = annual rate of change in annuity(in decimal form)

(1) Annual dollar income or cost (assumed to occur at the end of each year)

(a) If $r \neq p$: $V_o = [V/(p-r)] \times \{1-[(1+r)/(1+p)]^m\}$

(b) If $r = p$: $V_o = [V/(1+p)][m]$

(2) Periodic dollar income or cost

(a) If $a > n$: $V_o = 0$

(b) If $a \leq n$: $V_o = V_a/(1+p)^a$

(3) Terminal value $V_o = V_n/(1+p)^n$

(4) Physical yield value

(a) If $a>n$: $V_o = 0$

(b) If $a = n$: $V_o = FYV_n / (1+p)^n$

(c) If $a < n$: $V_o = IYV_a/(1+p)^a$

All incomes, costs, and physical yield values are assumed to occur at the end of the year specified as the age of occurrence.

Search Procedure for Internal Rate of Return

The iterative search procedure is based on that of Hall.[9] Initially, all values are discounted at a low rate of interest. If the discounted net worth is positive, this rate is incremented in steps of .5 percent until the net worth changes from a positive to negative value, i.e., until the IRR is bracketed. Successive approximations are then made by

[9] *See footnote 1.*

altering the discount rate by — .1 percent, + .01 percent, and finally —.005 percent. At this point the search is terminated.

This procedure assumes that the undiscounted sum of incomes exceeds the undiscounted sum of costs. If this is not true, no search for the IRR will be made and an appropriate diagnostic will be printed.

Program Documentation

This part of the paper is written primarily for the computer programmer-technician. Included is a listing of the computer source program and supporting materials.

Computer Requirements

The program was written in a slightly modified form of FORTRAN II for the Control Data Corporation 1604 computer of the Numerical Analysis Center, University of Minnesota. An attempt has been made to avoid using those characteristics peculiar to the CDC 1604 that would limit the use of this program on IBM or other equipment.

As the program is now written, a computer with a 16,000-word core storage capacity plus storage for a FORTRAN compiler is needed. No magnetic tapes or other peripheral storage devices are required. Since the "building block" approach of subroutines has been used, the computer must be able to perform the proper linkages.

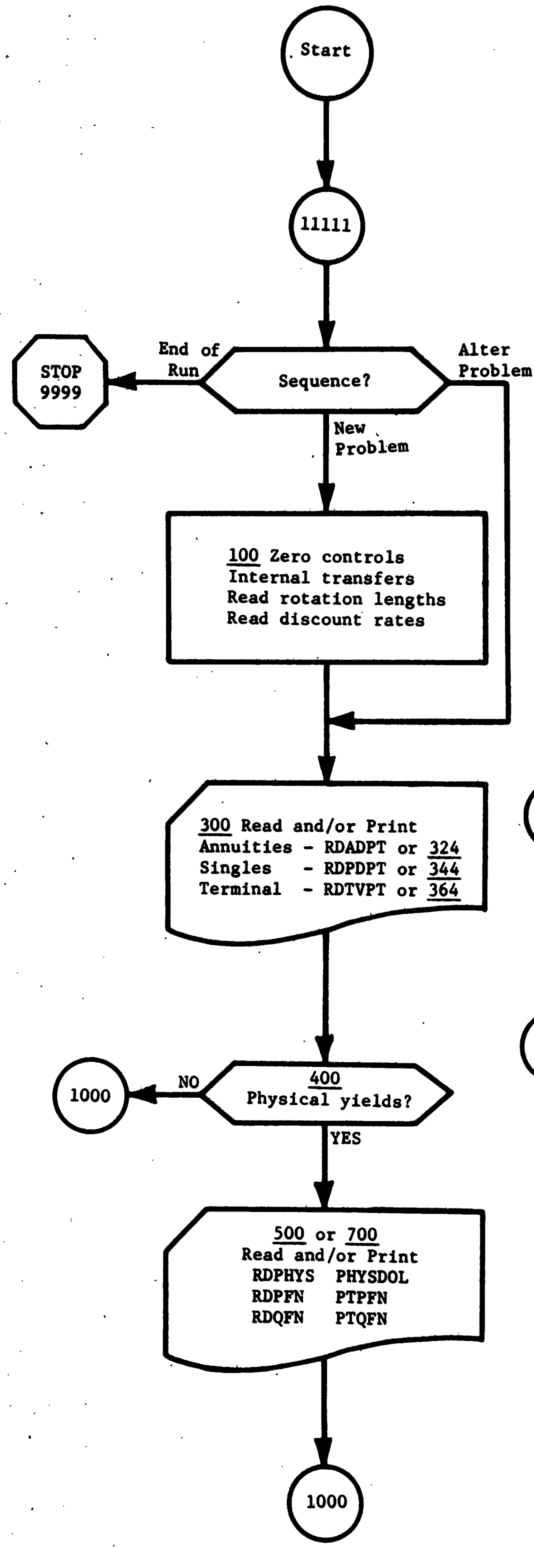
Limits on Input Data

The program arrays are dimensioned in such a fashion that the following restrictions on numbers of input cards must be observed.

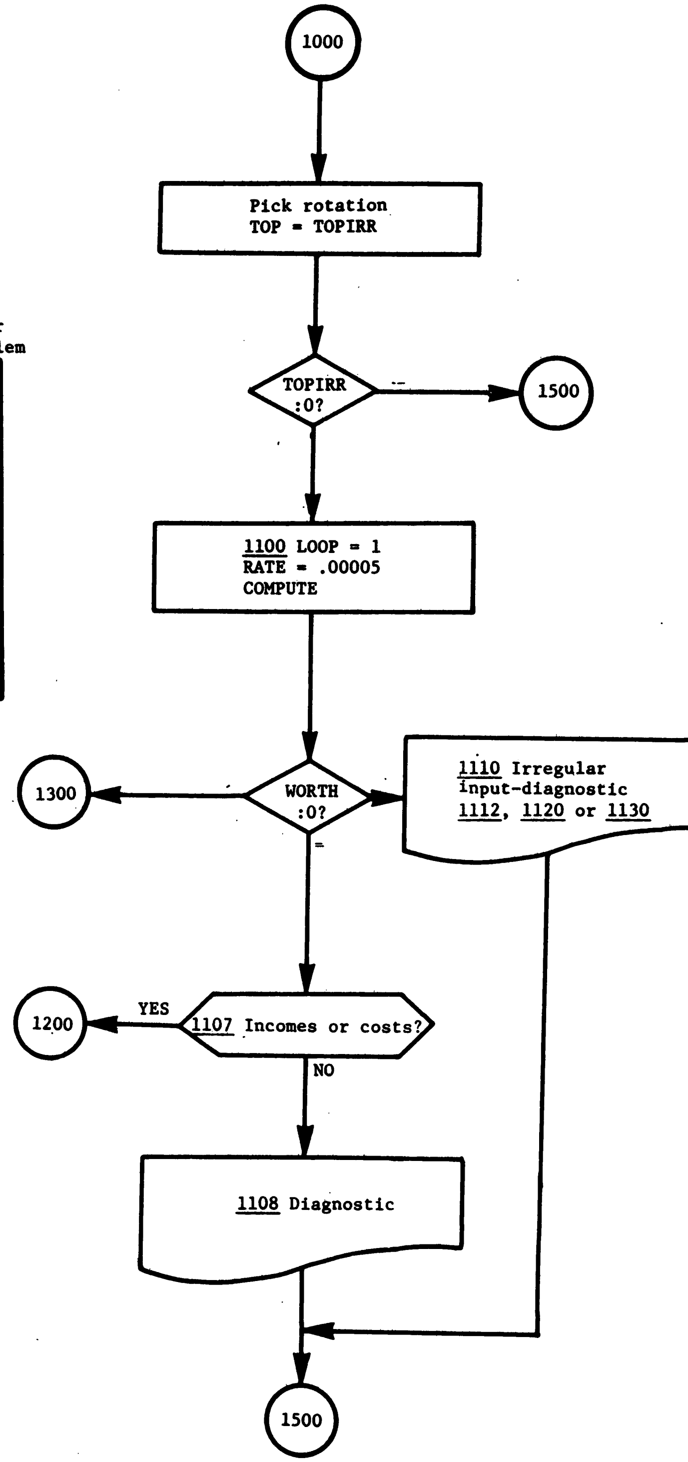
Type of input card	*Number of input cards in a single new or altered problem*
0. Control	Must be 1
1. Description	No restrictions
2. Rotation lengths	New problem — must be 1. Altered problem — none allowed
3. Discount rates	New problem — 0 or 1 Altered problem — none allowed
4. Annual payment	Maximum of 70
5. Single payment	Maximum of 70
6. Terminal value	0 or 1
7. Physical yield	Maximum of 270
8. Price function 9. Quality function	Must be as many of each as there are physical yield products — maximum of 9 each

Flow Chart and Listings

A flow chart (fig. 13) was prepared to assist in interpreting the main program, which provides general control through the problem input parameters of the Control card. The underlined and encircled numbers refer to FORTRAN statement numbers in the program listing. Similarly, subprograms are referenced by their (capitalized) names, such as RDADPT in the fifth block.

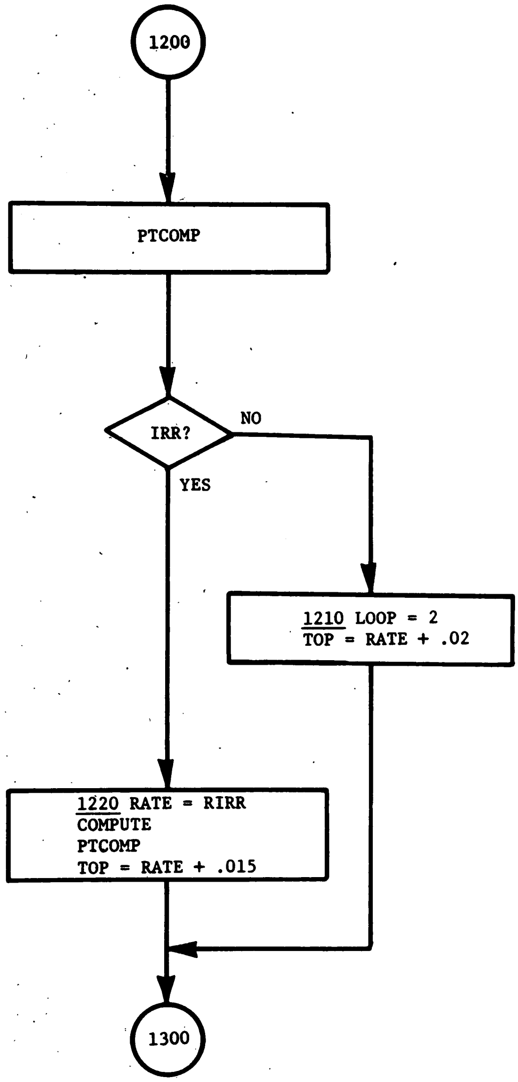


Sequence control input of new or altered problem.

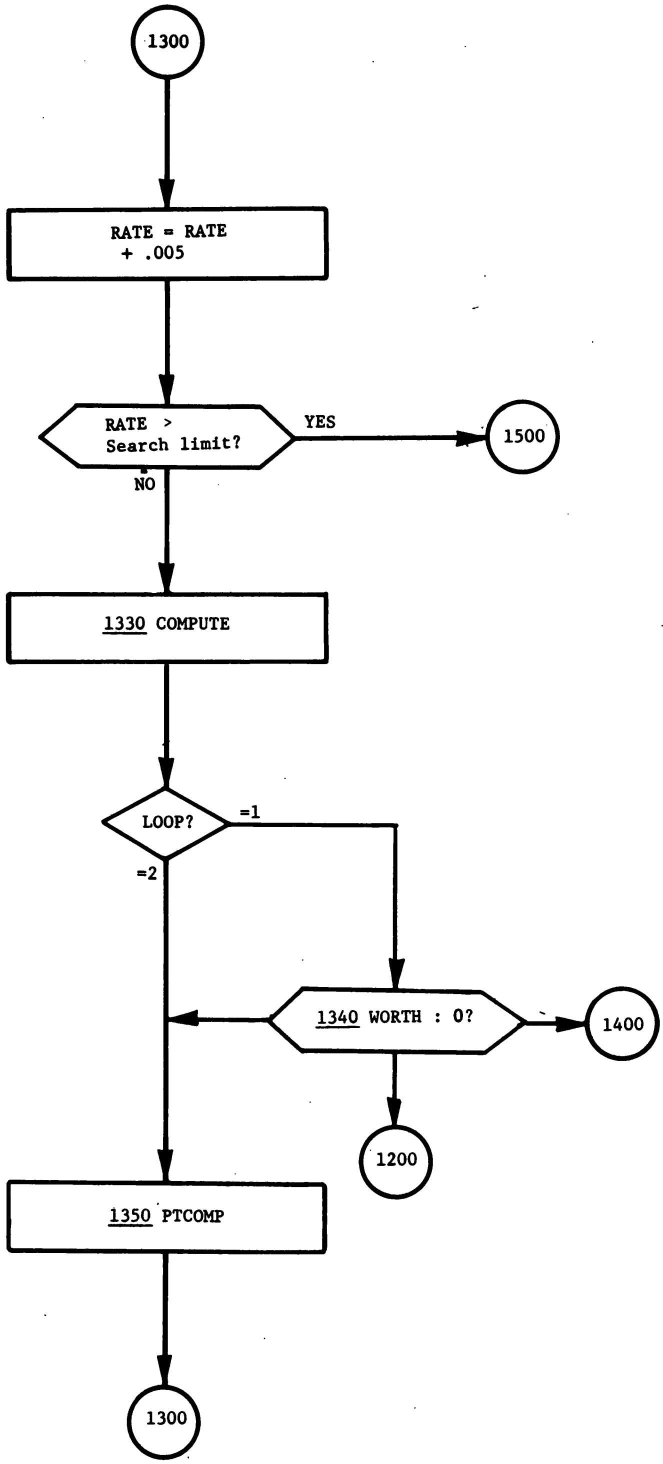


Test for positive IRR. If irregular inputs, print diagnostic.

FIGURE 13. — Flow chart of NCRETURN program.

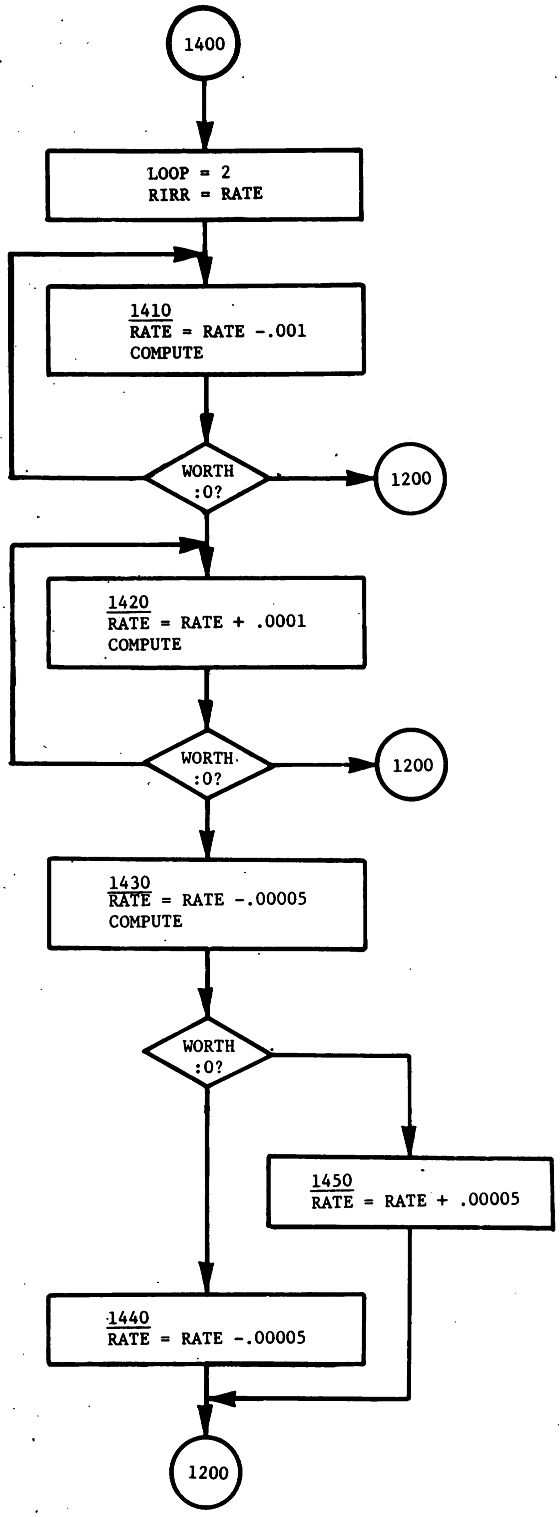


Print discounted values. If rate is IRR, adjust the search limit.

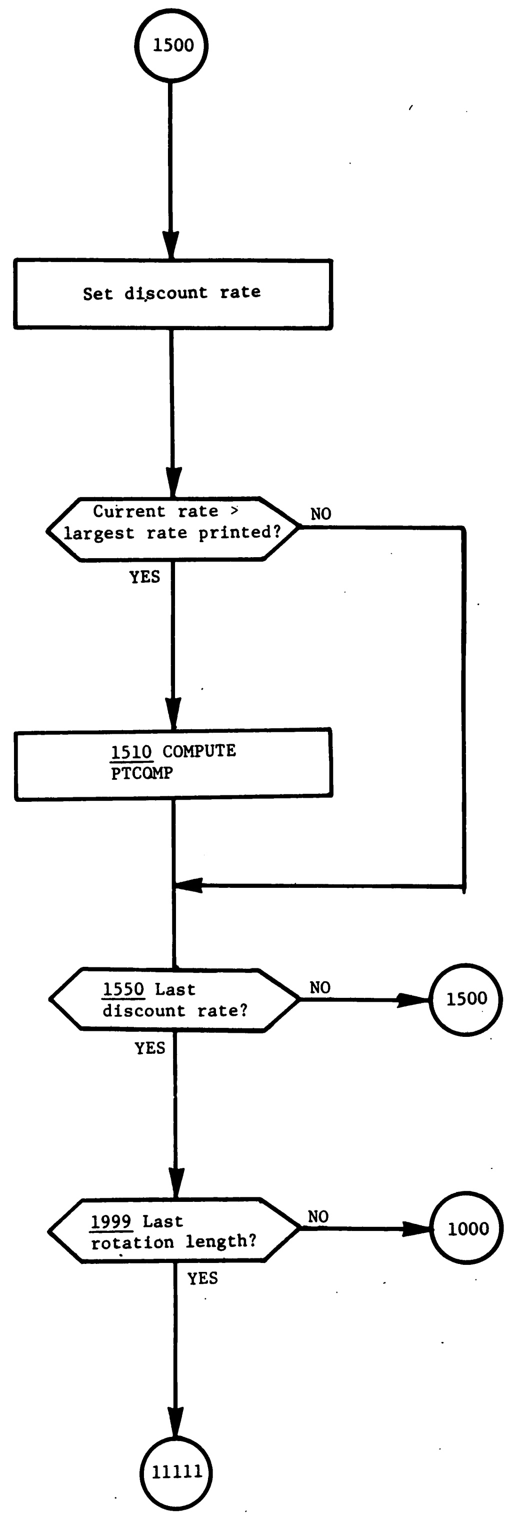


Increment discount rate by 1/2% until net worth becomes negative; then use iterative procedure.

FIGURE 13 cont'd



Iterative procedure to find IRR to nearest .01%.



Calculations using user-applied discount rates.

FIGURE 13 cont'd

```
      PROGRAM NCRETURN
      DIMENSION A(70,3), P(70,2), PY(270,8), PFN(9,10), QFN(9,7)
      DIMENSION H(270,3), DR(19), NY(26), JJ(11), IDPRO(9)
      COMMON A, P, PY, PFN, QFN, H
      NOPROB = 0
C
C        A COMPUTER PROGRAM FOR EVALUATING LONG-TERM FORESTRY INVESTMENTS
C
11111 NOPROB = NOPROB + 1
      PRINT 1, NOPROB
    1 FORMAT ( 1H1, 19X, 40HNORTH CENTRAL FOREST EXPERIMENT STATION
     1 10H(U.S.D.A.) / 36X, 16HPROGRAM NCRETURN,45X,11HPROBLEM NO,I3// )
C                                 READ CONTROL CARD
      READ 3, JJ, TOP, K, A1, A2, A3, KD
    3 FORMAT (I2,2X,I1,1X,8I1,2X,I1,2X,F5.5, 6X,I8,3A8, 17X,I1 )
      IF ( KD ) 9900, 5, 9900
 9900 STOP 9900
    5 IF( JJ(2) )  12, 12, 8
    8 READ 10, KD
   10 FORMAT (50H
     1 28H                                 , I2 )
      PRINT 10
      IF ( KD - 1 )  12, 8, 9901
 9901 STOP 9901
   12 IF ( JJ(1) ) 100, 9998, 200
 9998 PRINT 9999
 9999 FORMAT ( // 10X,  30HNORMAL END OF PROGRAM NCRETURN    )
      STOP 9999
C
  100 NAD = 0
      NPD = 0
      NPY = 0
      TV  = 0.
      JOB = K
      PC1 = A1
      PC2 = A2
      PC3 = A3
      NDR = 0
      KDP = JJ(11)
C                                 READ ROTATION LENGTHS
      READ 112, NY, KD
  112 FORMAT ( 26I3, 1X, I1 )
      IF ( KD - 2 )  9902, 116, 9902
 9902 STOP 9902
  116 I = 0
  118 I = I + 1
      IF (NY(I)) 9902, 120, 118
  120 NRL =  I - 1
C                                 READ DISCOUNT RATES
      IF ( JJ(3) ) 9903, 134, 122
  122 READ 124, DR, KD
  124 FORMAT ( 19F4.4, 3X, I1 )
      IF ( KD - 3 )9903, 126, 9903
 9903 STOP 9903
  126 I = 0
  128 I = I + 1
      IF  ( DR(I) )  9903, 130, 128
  130 NDR = I - 1
  134 IF (TOP)  300, 140, 304
  140 TOPIRR = .20
C
  200 IF ( K ) 204, 212, 204
  204 JOB = K
      PC1 = A1
      PC2 = A2
      PC3 = A3
  212 IF (TOP)  300, 308, 304
C
  300 TOPIRR = 0.
         GO TO 308
  304 TOPIRR = TOP
  308 PRINT 309, JOB, PC1, PC2, PC3
  309 FORMAT ( 40X, I8, 3A8 )
      IF(JJ(11)) 312,312,310
  310 PRINT 311
  311 FORMAT(20X,23HOUTPUT ON PUNCHED CARDS)
  312 PRINT 313
  313 FORMAT ( // 10X, 24HINCOME AND COST SCHEDULE   / )
      IF ( NAD + NPD + XFIXF(TV) + JJ(4) + JJ(5) + JJ(6) )  320, 314,320
  314 PRINT 316
  316 FORMAT ( 10X,40HPROBLEM HAS NO ANNUAL OR SINGLE PAYMENTS / )
         GO TO 400
  320 PRINT 321
  321 FORMAT ( 25X, 6HANNUAL, 5X, 9HINCOME OR  / 3X, 4HTYPE, 5X, 4HITEM,
     1   3X, 3HAGE, 3X, 6HCHANGE, 8X, 4HCOST, 7X, 11HDESCRIPTION  / )
C                                 ANNUAL PAYMENTS
      IF ( JJ(4) )  324, 324, 322
  322 CALL RDADPT (NAD)
         GO TO 340
  324 DO  337        I = 1, NAD
      IF (A(I,1) - 1000.) 330, 326, 330
  326 PP = 0.
      GO TO 334
  330 PP = A(I,1)
  334 PRINT 336, PP, A(I,2), A(I,3)
  336 FORMAT ( 3X, 9HANNUAL, 7X, F7.0, 2X, F6.5, 3X, E12.6 )
  337 CONTINUE
C                                 SINGLE PAYMENTS
  340 IF ( JJ(5) )  344, 344, 342
  342 CALL RDPDPT (NPD)
         GO TO 360
  344 DO  354        I = 1, NPD
  354 PRINT 356, P(I,1), P(I,2)
  356 FORMAT ( 3X, 6HSINGLE, 7X, F7.0, 11X, E12.6 )
C                                 TERMINAL VALUE
  360 IF ( JJ(6) ) 364, 364, 362
  362 CALL RDTVPT (TV)
         GO TO 400
  364 IF ( TV )  366, 400, 366
  366 PRINT 368, TV
  368 FORMAT ( 3X, 8HTERMINAL, 23X, E12.6 )
C                                 PHYSICAL UNITS OF INPUT
  400 IF ( JJ(7) )  600, 600, 500
  500 NPROD = JJ(7)
      CALL RDPHYS (NPY)
      CALL RDPFN (NPROD, PFID, IDPRO)
      CALL RDQFN (NPROD, QFID)
      CALL PTPFN (NPROD, PFID, IDPRO)
      CALL PTQFN (NPROD, QFID, IDPRO)
      CALL PHYSDOL (NPY, JOB)
         GO TO 1000
  600 IF ( JJ(1) )  602, 9998, 610
  602 PRINT 604
  604 FORMAT ( / 10X,  29HPROBLEM HAS NO PHYSICAL YIELD )
         GO TO 1000
  610 IF (NPY) 602, 602, 700
C                                 ALTER PHYSICAL YIELDS
  700 IF (JJ(8)) 710, 710, 702
  702 CALL RDPHYS (NPY)
  710 IF (JJ(9)) 720, 720, 712
  712 CALL RDPFN (NPROD, PFID, IDPRO)
  720 CALL PTPFN (NPROD, PFID, IDPRO)
      IF (JJ(10))    730, 730, 722
  722 CALL RDQFN (NPROD, QFID)
  730 CALL PTQFN (NPROD, QFID, IDPRO)
      CALL PHYSDOL (NPY, JOB)
         GO TO 1000
C                                               .....END OF INPUT:....
C                                               .....COMPUTATIONS:....
 1000 DO 1999        II = 1, NRL
      AGE = FLOATF(NY(II))
      PRINT 1010, NY(II),II,NRL,NOPROB
 1010 FORMAT (1H1, 20X, 22H.....ROTATION LENGTH =, I4,11H YEARS......
     1 20X,6HRL NO.,I3,3H OF,I3,14H - PROBLEM NO.,I3 //)
      PRINT 1012
 1012 FORMAT ( 20X, 39HTABLE OF DISCOUNTED VALUES (IN DOLLARS)  /
     1   10X, 8HDISCOUNT, 3(4X, 10HDISCOUNTED), 4X, 8HINFINITE, 1X,
     2   9HROTATIONS / 12X, 4HRATE, 8X, 6HINCOME, 8X, 5HCOSTS, 7X,
     3   9HNET WORTH, 5X, 17HADJUSTMENT FACTOR  / )
 1018 TOP = TOPIRR
      IF (TOPIRR) 1500, 1500, 1100
```

```
C                                          .....PRELIMINARY TEST.....
 1100 LOOP = 1
      RATE = ,00005
      CALL COMPUTE (RATE, AGE, TV, WORTH, COST, TAKE, NAD, NPD, NPY)
      IF (WORTH ) 1110, 1107, 1105
 1105 RATE = 0,
      GO TO 1300
 1107 IF (COST + TAKE ) 1200, 1108, 1200
 1108 PRINT 1109
 1109 FORMAT ( /// 20X, 34HNO INCOME OR COST INPUT TO PROGRAM )
      GO TO 1500
 1110 IF (TAKE ) 1112, 1112, 1115
 1112 PRINT 1113
 1113 FORMAT ( /// 20X, 26HNO INCOME INPUT TO PROGRAM )
      GO TO 1500
 1115 TOP = 0,
      RATE = ,999
      CALL COMPUTE(RATE,AGE,TV,WORTH,COST,TAKE,NAD,NPD,NPY)
      IF(WORTH) 1120,1130,1130
 1120 PRINT 1122
 1122 FORMAT ( /// 20X,    39HINTERNAL RATE OF RETURN IS NON-POSITIVE/)
      GO TO 1500
 1130 PRINT 1131
 1131 FORMAT(/// 20X,45HPOSITIVE IRR EXISTS BUT RETURNS PRECEDE COSTS/)
      GO TO 1500
C                                    .....PRINT OF INT, RATE OF RETURN,...
 1200 PRINT 1202
 1202 FORMAT ( / 1H*, 2X, 5HIRR =  )
      CALL PTCOMP (JOB, PC1, PC2, PC3, PFID, QFID, RATE, WORTH,
     1                COST, TAKE, NY(II), 1, TV, KDP)
      PRINT 1205
 1205 FORMAT ( )
      GO TO ( 1410, 1220), LOOP
 1210 LOOP = 2
      TOP = RATE + ,02
      GO TO 1300
 1220 RATE = RIRR
      CALL COMPUTE (RATE, AGE, TV, WORTH, COST, TAKE, NAD, NPD, NPY)
      CALL PTCOMP (JOB, PC1, PC2, PC3, PFID, QFID, RATE, WORTH,
     1                COST, TAKE, NY(II), 2, TV, KDP)
      TOP = RATE + ,020
C                                .....SEARCH FOR INT, RATE OF RETURN,....
 1300 RATE = RATE + ,005
      IF(RATE - TOP) 1330,1330,1310
 1310 GO TO ( 1315, 1500), LOOP
 1315 PRINT 1320, TOPIRR
 1320 FORMAT ( / 20X,46HIRR EXCEEDS SPECIFIED MAXIMUM SEARCH LIMIT OF
     1  8HTOPIRR =, F8,6 / )
      GO TO 1500
 1330 CALL COMPUTE (RATE, AGE, TV, WORTH, COST, TAKE, NAD, NPD, NPY)
      GO TO ( 1340, 1350), LOOP
 1340 IF (WORTH) 1400, 1200, 1350
 1350 CALL PTCOMP (JOB, PC1, PC2, PC3, PFID, QFID, RATE, WORTH,
     1                COST, TAKE, NY(II), 2, TV, KDP)
      GO TO 1300
C                                          .....ITERATIVE SOLUTION:....
 1400 LOOP = 2
      RIRR = RATE
 1410 RATE = RATE -,001
      CALL COMPUTE (RATE, AGE, TV, WORTH, COST, TAKE, NAD, NPD, NPY)
      IF (WORTH) 1410, 1200,1420
 1420 RATE = RATE + ,0001
      CALL COMPUTE (RATE, AGE, TV, WORTH, COST, TAKE, NAD, NPD, NPY)
      IF (WORTH) 1430, 1200, 1420
 1430 RATE = RATE - ,00005
      CALL COMPUTE (RATE, AGE, TV, WORTH, COST, TAKE, NAD, NPD, NPY)
      IF (WORTH) 1440, 1450, 1450
 1440 RATE = RATE - ,00005
      GO TO 1200
 1450 RATE = RATE + ,00005
      GO TO 1200
C
 1500 DO  1550      I = 1, NDR
      IF (DR(I) - TOP) 1550, 1550, 1510
 1510 CALL COMPUTE (DR(I), AGE, TV, WORTH, COST, TAKE, NAD, NPD, NPY)
      CALL PTCOMP (JOB, PC1, PC2, PC3, PFID, QFID, DR(I), WORTH,
     1                COST, TAKE, NY(II), 2, TV, KDP)
 1550 CONTINUE
 1999 CONTINUE
```

```
      FUNCTION SOP1 (PP, QQ, SUM)
      SOP1 = PP * SUM + QQ * SUM * SUM
      END
C
      SUBROUTINE RDADPT (NAD)
      DIMENSION A(70,3),P(70,2), PY(270,8),PFN(9,10), QFN(9,7),H(270,3)
      DIMENSION D( 8)
      COMMON A, P, PY, PFN, QFN, H
      I = 0
    1 I = I + 1
      READ 3, ITEM, (A(I,J), J = 1,3), D, KD
    3 FORMAT ( A3, 2X, F3.0, 2X, F5.5, 2X, F11.0, 2X, 8A6, I2 )
      PRINT 7, ITEM, (A(I,J), J = 1,3), D
    7 FORMAT ( 3X, 9HANNUAL, 4X, A3, F7.0,2X, F6.5,3X, E12.6,4X, 8A6 )
      IF ( A(I,1) ) 13, 13, 15
   13 A(I,1) = 1000.
   15 IF (KD*KD-16) 9904, 19, 9904
 9904 STOP 9904
   19 IF (KD) 25, 9904, 1
   25 NAD = I
      END
C
      SUBROUTINE RDPDPT (NPD)
      DIMENSION A(70,3),P(70,2), PY(270,8),PFN(9,10), QFN(9,7),H(270,3)
      DIMENSION D( 8)
      COMMON A,P, PY, PFN, QFN, H
      I = 0
    1 I = I + 1
      READ 3, ITEM, P(I,1), P(I,2), D, KD
    3 FORMAT ( A3, 2X, F3.0, 9X, F11.0, 2X, 8A6, I2 )
      PRINT 7, ITEM, P(I,1), P(I,2), D
    7 FORMAT ( 3X, 9HSINGLE, 4X, A3, F7.0, 11X, E12.6, 4X, 8A6 )
      IF (KD * KD - 25) 9905, 19, 9905
 9905 STOP 9905
   19 IF (KD) 25, 9905, 1
   25 NPD = I
      END
C
      SUBROUTINE RDTVPT (TV)
      DIMENSION D(8)
      READ 3, ITEM, TV, D, KD
    3 FORMAT ( A3, 14X, F11.0, 2X, 8A6, 1X, I1)
      PRINT 7, ITEM, TV, D
    7 FORMAT (3X, 8HTERMINAL, 2X, A3, 18X, E12.6, 4X, 8A6 )
      IF (KD - 6)  9906, 25, 9906
 9906 STOP 9906
   25 END
C
      SUBROUTINE RDPHYS (NPY)
      DIMENSION A(70,3),P(70,2), PY(270,8),PFN(9,10), QFN(9,7),H(270,3)
      COMMON A, P, PY, PFN, QFN, H
      PRINT 50
   50 FORMAT( // 10X,28HSCHEDULE OF PHYSICAL YIELDS  )
   59 PRINT 60
   60 FORMAT (/25X,12HINTERMEDIATE, 7X,5HFINAL/3X,4HTYPE,3X,
     1 9HPRODUCT  ,3HAGE,6X,7H YIELD ,8X,7H YIELD ,7X,8HFACTOR 1,7X,
     28HFACTOR 2, 7X, 8HFACTOR 3, 7X, 8HFACTOR 4 / )
      I = 0
    1 I = I + 1
      READ 3, (PY(I,J), J = 1,8), KD
    3 FORMAT ( 3X, F1.0, 1X, F3.0, 6F10.0, 10X, I2 )
      PRINT 7, (PY(I,J), J = 1,8)
    7 FORMAT ( 3X, 5HYIELD, 4X, F2.0, 5X, F4.0, 2X, 6(E12.6, 3X) )
      IF ( KD * KD - 49 ) 9907, 19, 9907
 9907 STOP 9907
   19 IF (KD) 25, 9907, 1
   25 NPY = I
      PRINT 27
   27 FORMAT ( /// )
      END
C
      SUBROUTINE RDPFN (NPROD, PFID,IDPRO)
      DIMENSION A(70,3),P(70,2), PY(270,8),PFN(9,10), QFN(9,7),H(270,3)
      DIMENSION IDPRO(9)
      COMMON A, P, PY, PFN, QFN, H
      DO 4  I = 1,NPROD
    1 READ 3, PFID, J, (PFN(J,K), K=1,10),KD
    3 FORMAT(A3,I1,6F8.0,3F7.0,F5.5,1X,I1)
      IF(KD-8) 9908,4,9908
```

```
      SUBROUTINE RDQFN (NPROD, QFID)
      DIMENSION A(70,3),P(70,2), PY(270,8),PFN(9,10), QFN(9,7),H(270,3)
      COMMON A, P, PY, PFN, QFN, H
      DO 4  I = 1,NPROD
    1 READ 3, QFID, J, (QFN(J,K), K = 1,7),KD
    3 FORMAT (A3, I1, 7F8.0,19X,I1)
      IF(KD-9) 9909,4,9909
 9909 STOP 9909
    4 CONTINUE
      END
C
      SUBROUTINE PTPFN (NPROD, PFID,IDPRO)
      DIMENSION A(70,3),P(70,2), PY(270,8),PFN(9,10), QFN(9,7),H(270,3)
      DIMENSION IDPRO(9)
      COMMON A, P, PY, PFN, QFN, H
      PRINT 71
   71 FORMAT ( /// 10X, 27HPRICE FUNCTION COEFFICIENTS // 34X,
     1    10H(FACTOR 1),14X,5H(AGE),6X,
     2                           7H(AGE) *, 6X, 3HJOB, 4X, 10H(JOB CON.),
     3    3X, 7H(AGE) *  / 2X, 9HPFID PROD, 2X,8HCONSTANT, 3X,
     4    8HFACTOR 1,3X,7HSQUARED,7X, 3HAGE, 5X, 7HSQUARED,3X,
     5    20H(FACTOR 1)  CONSTANT,3X,7HSQUARED,3X,15H(JOB CON.)   OR / )
      DO 1  I = 1, NPROD
      J = IDPRO(I)
    1 PRINT 3,PFID,J,(PFN(J,K),K = 1,10)
    3 FORMAT ( 3X,A3,2X,I1,3X, 9(F10.5,1X), F6.4)
      END
C
      SUBROUTINE PTQFN (NPROD, QFID,IDPRO)
      DIMENSION A(70,3),P(70,2), PY(270,8),PFN(9,10), QFN(9,7),H(270,3)
      DIMENSION IDPRO(9)
      COMMON A, P, PY, PFN, QFN, H
      PRINT 72
   72 FORMAT(///10X,29HQUALITY FUNCTION COEFFICIENTS
     1                           // 34X,10H(FACTOR 2), 12X, 11H(FACTOR 2)*,
     2    11X, 11H(FACTOR 3)*  / 2X, 9HQFID PROD, 2X, 8HCONSTANT, 3X,
     3    8HFACTOR 2,3X,7HSQUARED,4X, 8HFACTOR 3, 2X, 10H(FACTOR 3),
     4    2X, 8HFACTOR 4, 2X, 10H(FACTOR 4)    / )
      DO 1  I = 1,NPROD
      J = IDPRO(I)
    1 PRINT 3,QFID,J,(QFN(J,K),K = 1,7)
    3 FORMAT ( 3X,A3, 2X, I1, 3X, 7(E10.5, 1X) )
      END
C
      SUBROUTINE PHYSDOL (NPY, JOB)
      DIMENSION A(70,3),P(70,2), PY(270,8),PFN(9,10), QFN(9,7),H(270,3)
      COMMON A, P, PY, PFN, QFN, H
      PRINT 45
   45 FORMAT(1H1,10X,25HVALUE OF PHYSICAL YIELDS
     1     36H(PHYSICAL YIELD * PRICE * QUALITY)
     2             // 25X, 12HINTERMEDIATE, 7X, 5HFINAL  /  4X, 4HTYPE,
     3    2X, 7HPRODUCT, 2X, 3HAGE, 7X, 2( 5HYIELD, 10X) / )
      SUM = FLOATF(JOB)
      DO 29 I = 1, NPY
      J = XFIXF(PY(I,1))
      PP = PFN(J,1) + SQP1(PFN(J,2), PFN(J,3), PY(I,5))
     1              + SQP1(PFN(J,4), PFN(J,5), PY(I,2))
     2              + SQP1(PFN(J,7), PFN(J,8), SUM)
     3   +PFN(J,6)*PY(I,2)*PY(I,5) + PFN(J,9) * PY(I,2) * SUM
      PP = PP * (1. + PFN(J,10)) ** XFIXF(PY(I,2))
      QQ = QFN(J,1) + SQP1(QFN(J,2), QFN(J,3), PY(I,6))
     1   + QFN(J,4) * PY(I,7) + QFN(J,5)* PY(I,6)* PY(I,7)
     2   + QFN(J,6) * PY(I,8) + QFN(J,7)* PY(I,7)* PY(I,8)
      H(I,1) = PY(I,2)
      H(I,2) = PP * QQ * PY(I,3)
      H(I,3) = PP * QQ * PY(I,4)
   29 PRINT 31, J,(H(I,M), M=1,3)
   31 FORMAT(3X,5HYIELD, 5X,I1, 5X,F4.0,2X, 2(E12.6,3X) )
      END
C
      SUBROUTINE COMPUTE (R,AGE, TV, WORTH, COST, TAKE, NAD, NPD, NPY)
      DIMENSION A(70,3),P(70,2), PY(270,8),PFN(9,10), QFN(9,7),H(270,3)
      COMMON A, P, PY, PFN, QFN, H
      WORTH = 0.
      COST = 0.
      TAKE = 0.
  100 DO  199        I = 1, NAD
      IF(R-A(I,2)) 130,110,130
  110 K=XMIN1F(AGE,A(I,1))
      W=FLOATF(K)*A(I,3)/(1.+R)
      IF(W) 170,199,160
  130 W=A(I,3)/(R-A(I,2))
      W = W*( 1. - ((1. + A(I,2)) / (1. + R) ) **XMIN1F(AGE,A(I,1)))
      IF(W) 170,199, 160
  160 TAKE = TAKE + W
      GO TO 180
  170 COST = COST + W
  180 WORTH = WORTH + W
  199 CONTINUE
  300 DO  399        I = 1, NPD
      IF(P(I,1) -AGE) 320, 320, 399
  320 W=P(I,2) / (1.+ R) ** P(I,1)
      IF(W) 370, 399, 360
  360 TAKE = TAKE +W
      GO TO 380
  370 COST =COST + W
  380 WORTH =WORTH + W
  399 CONTINUE
  500 DO  599        I=1,NPY
      IF(H(I,1) -AGE) 530, 520, 599
  520 W = H(I,3)
      GO TO 540
  530 W = H(I,2)
  540 W=W / (1. +R) ** H(I,1)
       IF(W) 570, 599, 560
  560 TAKE = TAKE + W
      GO TO 580
  570 COST = COST + W
  580 WORTH = WORTH + W
  599 CONTINUE
  700 W = TV / (1. + R) ** AGE
      IF(W) 770, 799, 760
  760 TAKE = TAKE + W
      GO TO 780
  770 COST = COST + W
  780 WORTH = WORTH + W
  799 CONTINUE
      END
C
      SUBROUTINE PTCOMP (JOB,PC1,PC2,PC3,        PFID, QFID, R, WORTH,
     1                COST, TAKE, N,       K, TV, KDP)
      ADJ = 1. + 1./((1. + R)**N -1.)
      PRINT 5, R, TAKE, COST, WORTH, ADJ
    5 FORMAT (10X, F7.4, 2X, 3(F13.3, 1X), 6X, E13.7)
      IF(KDP) 7, 7, 9
    7 RETURN
    9 IF(TV) 11, 13, 11
   11 JJ = 1
      GO TO 15
   13 JJ = 0
   15 PUNCH 17, JOB, PC1, PC2, PC3, PFID, QFID, N, R,TAKE,COST,JJ,ADJ,K
   17 FORMAT (I8, 3A8, 2A3, I3, F6.4, 2F9.2, I1, E13.7, I1)
      END
      END
```

SUBPROGRAMS

Most of the subprograms are used for input (I) and/or output (0). They provide flexibility in writing, using, and modifying the program.

Subprogram		Purpose
RDADPT	I/0	Annual payments
RDPDPT	I/0	Single payments
RDTVPT	I/0	Terminal value
RDPHYS	I/0	Physical yields
RDPFN	I	Price functions
PTPFN	0	Price functions
RDQFN	I	Quality functions
PTQFN	0	Quality functions
PTCOMP	0	Discounted values; printed and punch card output
PHYSDOL		Convert physical yields to (future) values
COMPUTE		Compute discounted income, cost, and net worth
SQP1		Facilitate computations of COMPUTE

In addition, the following standard FORTRAN library functions are used:

FLOATF	Float a fixed variable
XFIXF	Fix a floating variable
XMIN1F	Select minimum value

ARRAYS AND SIMPLE VARIABLES

The following listing defines all variables used in the NCRETURN program. A single FORTRAN name is associated with each variable, in subprograms as well as in the main program, except in the case of a few simple variables.

Principal arrays	Content
A(I,J) J=1,3 I=1, NAD	annual payments
J=1	age
J=2	annual change
J=3	income
DR(I) I=1, NDR	discount rates
H(I,J) J=1,3 I=1, NPY	future value of physical yields (calculated)
J=1	age
J=2	intermediate yield value
J=3	final yield value
JJ(I) I=1, 11	inputs specified on Control card
I=1	type of problem (-1, 0,+1)
I=2	description
I=3	rotation lengths
I=4	discount rates

Principal Arrays	Content
I=5	annual payments
I=6	single payments
I=7	terminal value
I=8	number physical products
I=9	price functions
I=10	quality functions
I-11	punched card output option
NY(I) I=1, NRL	rotation lengths
P(I,J) J=1,2 I=1, NPD	single payments
J=1	age
J=2	income
PFN(J,K) K=1,10 J=1, NPROD	price function coefficients
K=1	price function constant
K=2	coefficient of factor 1
K=3	coefficient of $(\text{factor } 1)^2$
K=4	coefficient of age
K=5	coefficient of $(\text{age})^2$
K=6	coefficient of $(\text{age}) \times (\text{factor } 1)^2$
K=7	coefficient of job constant
K=8	coefficient of $(\text{job constant})^2$
K=9	coefficient of (age) x (job constant)
K=10	% of annual change in price (dr)
PY(I,J) J=1,8 I=1, NPY	physical yields
J=1	product
J=2	age
J=3	intermediate yield
J=4	final yield
J=5	factor 1
J=6	factor 2
J=7	factor 3
J=8	factor 4
QFN(J,K)K=1,7 J=1, NPROD	quality function coefficients
K=1	quality function constant
K=2	coefficient of factor 2
K=3	coefficient of $(\text{factor } 2)^2$
K=4	coefficient of factor 3
K=5	coefficient of (factor 2) x (factor 3)
K=6	coefficient of factor 4
K=7	coefficient of (factor 3) x (factor 4)

Other variables	
ADJ	adjustment factor for infinite rotations
AA, AGE, N, NN, YRS	length of rotation or year of occurrence
COST, C	discounted total costs
D(I), ITEM	descriptive data
JOB	Job constant
J, I, IDPRO(I)	product identifiers
KD	card number for sequence check
KDP	punch card option

Other variables	Content
LOOP	rate of return computation control (2 if IRR found; 1, otherwise)
NAD	number of annual payments
NDR	number of discount rates specified
NOPROB	problem numbering control
NPD	number of single payments
NPROD	number of physical products
NPY	number of physical yields
NRL	number of rotation lengths
PC1, PC2, PC3	punched card output description
PFID	price function group identification
QFID	quality function group identification
RATE, RIRR, R	test internal rate of return
TAKE, T	discounted total incomes
TOPIRR, TOP	maximum search limit for internal rate of return
TV	terminal value
WORTH, W	discounted net worth
II, K, M, PP, QQ, SUM A1, A2, A3	dummy and temporary variables

Some Recent Research Papers of the North Central Forest Experiment Station

Thinning Red Pine for High Investment Returns, by Allen L. Lundgren. U. S. Forest Serv. Res. Pap. LS-18, 20 pp., illus. 1965.

Characteristics of Family Campers Using the Huron-Manistee National Forests, by David A. King. U.S. Forest Serv. Res. Pap. LS-19, 11 pp., illus. 1965.

Estimating Crown Fuel Weights of Red Pine and Jack Pine, by James K. Brown. U.S. Forest Serv. Res. Pap. LS-20, 12 pp., illus. 1965.

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Scleroderris Canker on National Forests in Upper Michigan and Northern Wisconsin, by Darroll D. Skilling and Charles E. Cordell. U.S. Forest Serv. Res. Pap. NC-3, 10 pp., illus. 1966.

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Joint Proceedings, Second Genetics Workshop of the Society of American Foresters and the Seventh Lake States Forest Tree Improvement Conference, October 21-23, 1965, by North Central Forest Experiment Station, U.S. Forest Serv. Res. Pap. NC-6, 110 pp., illus. 1966.

Designing Efficient Logging Systems for Northern Hardwoods, Using Equipment Production Capabilities and Costs, by R. B. Gardner. U.S. Forest Serv. Res. Pap. NC-7, 16 pp., illus. 1966.

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