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Simulating Timber and Deer Food Potential In Loblolly Pine Plantations

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SUMMARY

This computer program analyzes both timber and deer food production on managed forests, providing estimates of the number of acres required per deer for each week or month, yearly timber cuts, and current timber growing stock, as well as a cost and return analysis of the timber operation. Input variables include stand descriptors, controls on management, stumpage prices, and costs of various activities and practices. Equations and constants contained in the program estimate the production of various classes of deer food from these timber stand and management parameters. Foods are evaluated in terms of seasonal nutrient content and the metabolic requirements of white-tailed deer. The program is applicable to loblolly pine plantations in east Texas and Louisiana but can be readily modified for other species or areas.

Additional keywords: Timber management, forest management, simulation, deer habitat potential, wildlife foods, deer management, *Pinus taeda, Odocoileus virginianus.*

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INTRODUCTION

Southern foresters need to increase production of fast-growing pines greatly to meet projected demands for wood products. An obvious way to boost production is to increase the area devoted to pine plantations and to intensify their management. Such practices, of course, will affect food and cover for wildlife, including white-tailed deer (Odocoileus virginianus L.). Therefore, land managers will need to evaluate potential changes in deer habitat before deciding on a silvicultural plan for a particular area. If deer are to be maintained on the area, silvicultural prescriptions that benefit the deer herd without unacceptable effects on costs or timber yields should be a major goal.

Simulation on digital computers provides a means of examining the probable outcome of several courses of action without expending all the time and money otherwise needed for field trials. The particular set of activities that appears to best achieve the manager's goals can then be adopted.

Computer program TIMHAB, described in this guide, analyzes both timber and deer food production on managed forests, estimates timber data annually, evaluates timber costs and returns, and estimates deer foods weekly or monthly. Inputs and results are in units regularly used by forest and wildlife managers. Both timber and deer food data are estimated by summation of separate analyses for individual stands. By varying silvicultural activities, the effects of modifications can be evaluated in terms of both the timber enterprise and deer-carrying capacity.

TIMHAB contains equations and constants applicable to tree and understory species found in loblolly pine (Pinus taeda L.) plantations in east Texas and Louisiana. The program can be modified, however, for use with other tree species or geographic areas.

Information to be supplied by the program user includes the following:

1. Periods of growth of woody and herbaceous vegetation and of availability of acorns and other mast.
2. Rotation length, thinning and prescribed burning instructions, and other management controls.
3. Stumpage prices per 100 cubic feet and per 1,000 board feet.
4. Costs per acre of precommercial thinning, planting, prescribed burning, and administration.
5. Area, site index, site preparation method, years since cutting, years since burning, and working group assignment of each stand.
6. Average diameter (d.b.h.), average height, number of trees per acre, and age of each stand. Separate values are needed for the overstory pines, midstory hardwoods, and understory pines.

TIMHAB uses these data plus equations and constants contained in the program to compute the following:

1. For each week or month of each year, separate estimates of available digestible dry matter, crude protein, phosphorus, and gross energy expressed as deer-days of use per acre and as acres per deer. Estimates are based on accessible, preferred foodstuffs and estimated metabolic needs for growth of an average deer. Each

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category of food (grasses, forbs, browse twigs, browse leaves, berries and other soft mast, acorns, and mushrooms) is included in available supply only during the period when the category is eaten by deer. No reductions are made for deer already on the area or for consumption by other species.
2. Volume and value of the timber harvested each year.
3. Total for each year of the fixed costs and the costs of all activities.
4. Volume and value of the timber growing stock at the end of each year.
5. Rate of return from the timber operation on the initial growing stock value.

Returns from hunting leases are not included in the economic analyses. These can be added when more is known about deer population responses to variations in the food supply. Meanwhile, each program user should consider projected deer food changes in terms of their effect on lease income.

EXAMPLE AND AVAILABILITY

Types of information produced by TIMHAB are illustrated by the results of a hypothetical 10-year simulation tabulated in the Appendix. Total output consists of two pages reporting conditions at the beginning of simulation, one page of food potentials for each of the years simulated, and four pages of economic analyses. For brevity, only the first and tenth pages of the 10 annual summaries of deer food potential are shown.

The hypothetical planning unit consists of two working groups, one managed for sawlog production and one for pulpwood. Printed on the two pages headed "Conditions at Start of Simulation" are initial timber volumes and values and a record of the management options for each working group. Among other things, they report for working group 1 a sawlog rotation of 70 years, with each stand prescribed burned every 7 years beginning at stand age 22. For working group 2, the rotation is 30 years, with no intermediate cuts or burns (interval same as rotation). Deer-days of use and acres per deer are reported for 12 time units (i.e., months) each year. In the remaining pages, which report year-end status and deer food, values are for the planning unit, including both working groups.

The hypothetical situation was designed to perform most of the possible computations and is not suggested as a program of management for loblolly pine plantations. Numerous combinations of possible alternatives as well as published recommendations for management (Blair and Enghardt 1976) can be simulated by a user of TIMHAB.

TIMHAB was written in ANS standard FORTRAN IV and has been tested on XEROX 560, CDC 6400, and UNIVAC 1108 computers. Program length, including common blocks, is 23,100 (decimal) words.

A listing of the FORTRAN program or a source deck may be obtained from the Southern Forest Experiment Station, Box 7600 SFA Station, Nacogdoches, Texas 75962. Requests for punched cards should indicate whether a 026 (Hollerith) or a 029 (EBCDIC) character code is desired.

STATUS OF TIMHAB

TIMHAB is designed as an interim tool to be improved periodically as new and better information becomes available. To complete the model and computer program, some preliminary equations and constants are included, and a few options are provided for future use, for which necessary information is now lacking. These items are identified by comment statements in the program.

Simulation of an activity can indicate profitable areas of future studies and encourage reanalysis of existing data to obtain new information. TIMHAB is being described and made available now partly in the hope that it will stimulate and guide such effort. Work is already underway to obtain replacements for some of the preliminary equations and constants. To keep the program up-to-date as new information becomes available, the long job of programming need not be repeated since improvements require only localized changes.

TIMHAB is not yet a completed, operational management tool, and the effect of all the equations acting together will be unknown until the model is validated. Confidence in the results can be no greater than the degree of confidence that can be placed in all equations and constants. Reliability will increase, however, as the weaker equations and constants are replaced with improved versions. In the meantime, differences in the results of two or more runs are best examined in relation to each other, not as absolute numerical changes in timber or deer food production.

Validation of this simulation model in the usual manner is not now possible. Data on understory production of nutrients and on the metabolic needs of deer are scarce and expensive to obtain. Everything available was incorporated in the model described by the program. Data are now being obtained from long-term studies that will permit future tests of nutrient computations and overstory-understory interactions. Comparisons involving the timber equations are discussed elsewhere (Myers 1977).

One limited test of the program indicates that TIMHAB can produce reasonable results. Tree and understory growth, timber cutting, tree planting, and periodic burning on several stands in a deer enclosure were simulated for 12 years. Projected months of maximum and minimum potential carrying capacity, the pattern of seasonal change in capacity, and responses to timber treatments were as expected from studies of the actual system. Computed potential minimum carrying capacity was not materially different from that of similar stands studied elsewhere.

DESCRIPTION OF TIMHAB

Computer program TIMHAB consists of a main program and 19 subroutines that estimate the production of trees and understory vegetation, quantities of timber harvests and thinnings, costs and effects of other silvicultural operations, and carrying-capacity for white-tailed deer. To facilitate future modification and improvement of the program, all equations and constants are contained in five subroutines.

Operations performed by each routine and the sources of equations and constants are described in this section and are identified by comment statements in the program. Subsequent sections of this paper describe the variables of the data deck and the procedures for program modification.

Several terms used in subroutine descriptions are defined below. Their correct usage is essential for proper preparation of a data deck.

1. Planning unit--the entire area simulated by one computer run. It could be as large as 199,980 acres, in the unlikely event that each of the subunits should be of maximum size.
2. Planning subunit--a subdivision of the planning unit. Each must be uniform in stand age and structure, silvicultural treatment, etc., and therefore a subunit corresponds to a timber manager's definitions of a stand. The term subunit is used when reference is made to both the timber stand and the understory. TIMHAB now permits simulation of a planning unit with 200 subunits of up to 9,999.9 acres each. It can be modified to increase the allowable number of subunits.
3. Working group--a series of subunits or stands of the same forest type and managed by the same silvicultural system. Up to four working groups may be defined by the program user. Working group 4 must be reserved for hardwood stands, even though growth and other equations for hardwood stands do not yet appear in TIMHAB.
4. Midstory--hardwood trees and shrubs, growing in pine stands, that are tall enough to have a measurable diameter 4.5 feet above the ground. The term does not include a hardwood understory in a hardwood stand.

Main Program

The main program performs the following operations:

1. Calls 12 subroutines to perform computations and other operations in the proper sequence (fig. 1). Each subunit is processed for each week or month of every year, and results for all subunits are combined for printing.
2. Tests whether each class of food (trees, herbaceous vegetation, shrubs, berries and other soft mast, acorns, and mushrooms) is in its period of growth or dormancy and adjusts quantities for growth or losses.
3. Calls a subroutine to determine if a scheduled thinning, prescribed burning, or regeneration cutting is due. Tree stands may be regenerated by (1) clearcutting and planting, (2) seed-tree method, (3) two-cut shelterwood, or (4) three-cut shelterwood.
4. Increases the (1) age of each stand, (2) number of growing seasons completed, and (3) number of years since cutting and burning, by an increment equal to the simulation time unit (week or month).

Subroutine INIT

INIT is called by the main program to assign an initial value of zero to numerous variables.

Subroutine BASIS

BASIS is called by the main program to read initial values from the data cards described in the next section. The fraction of a year represented by the selected time unit, 1 week or 1 month, is computed.

Subroutine ERROR

ERROR is called by the main program to test the values of variables entered by the program user that define (1) growing seasons, (2) number of years to be simulated, (3) number of simulation periods in 1 year, (4) length of cutting cycle, and (5) length of rotation. Any improper value terminates the computer run with an error message. Cycle and rotation lengths are tested only for working group 1, to allow processing of fewer than four working groups.

Subroutine START

START is called by the main program to compute initial conditions on the planning unit on January 1 of the first year of simulation and to determine several constants needed in subsequent computations. The following values are determined:

1. Proportions of annual production of browse, herbage, and soft mast produced during each period of the growing season.
2. Number of weeks or months in the non-growing season, separately for browse, herbage, and soft mast, from information on data card type 3.
3. Initial growing stock volumes in board and cubic feet and their value. Cubic volumes do not include volumes of sawlogs or of trees in stands younger than a minimum age specified by the program user.
4. Decimal parts of a year to be added to stand ages read from the data cards. This modification distributes dates of simulated thinnings and regeneration cuttings throughout the year. Amounts added to each age are computed with a simple congruential pseudorandom number generator in START.
5. Theoretical initial number of pine trees per acre. The equation for mortality in unthinned stands uses initial density as an independent variable. For plantations already established when simulation begins, initial density is computed from a restatement of this equation. Plantations created during the simulation period will each contain the number of trees specified by the program user.
6. Ovendry weights of accessible and preferred grasses, forbs, soft mast, browse leaves, and browse twigs present when simulation begins on January 1 of the first year. An initial amount is computed separately for each planning subunit, on the basis of records of prior cutting and prescribed burning from data cards read by subroutine BASIS. Weights of acorns and mushrooms are not computed by START but by ETEX.

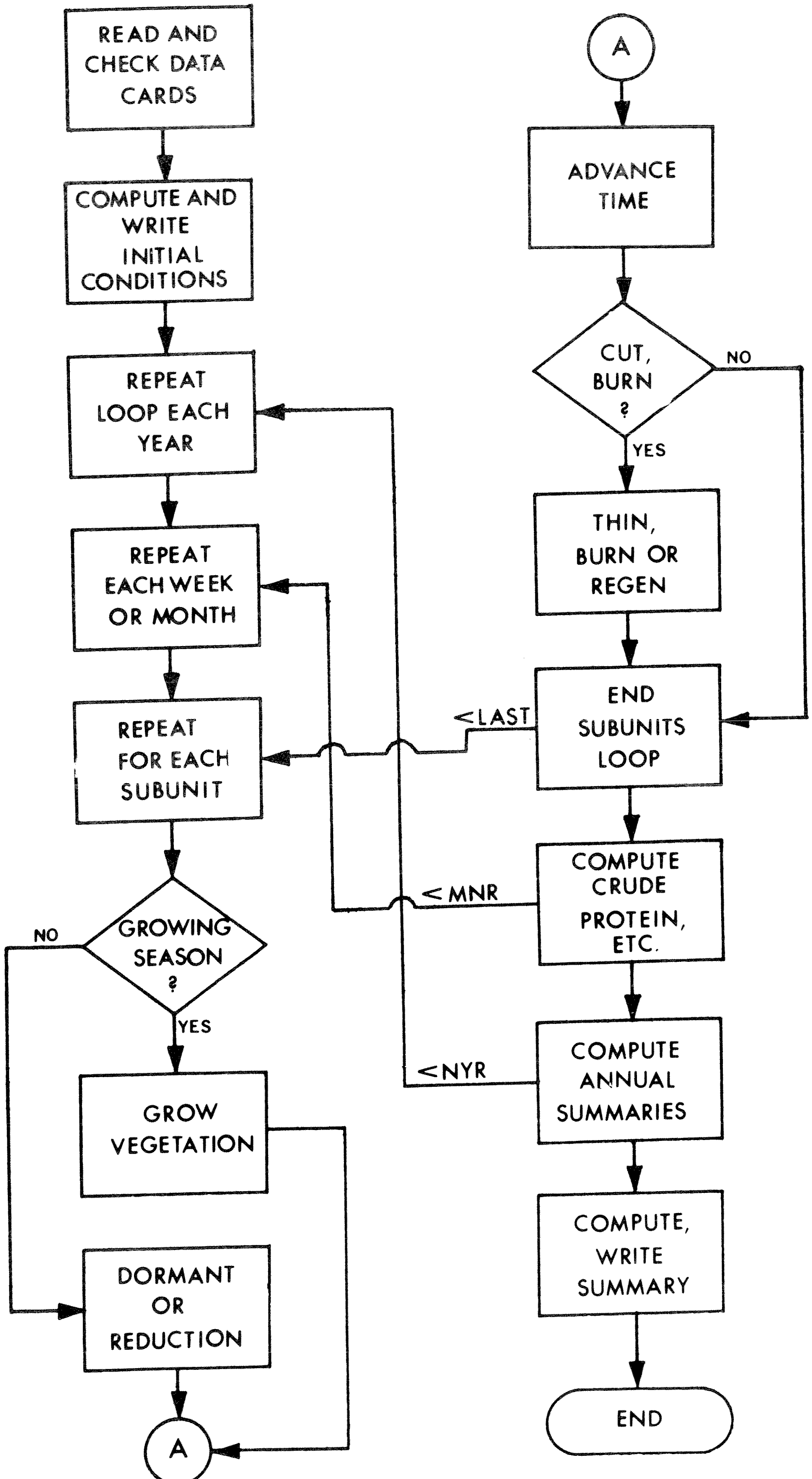

Figure 1.—*Sequence of operations in program TIMHAB. Test for growing season is made for each food source every time that step in the sequence is reached.*

Subroutine BEGIN

BEGIN is called by the main program to write two pages describing conditions at the start of the simulation period (Appendix). These are the first two pages written during the simulation run; they report (1) initial volume and value of the growing stock, (2) controls on management for each working group, (3) unit costs and prices, and (4) the season of use by deer of each of seven classes of food.

Subroutine UNDR

UNDR is called by the main program and by subroutine START to select two subroutines that compute the increases or decreases of understory vegetation, fruits, or acorns. Selection is based on a locality code on a data card for each subunit. In its present form, TIMHAB contains two subroutines applying to understories and deer foods in loblolly pine plantations in east Texas and Louisiana (locality code 1). Subroutine ETXBEG computes amounts of each type of forage present at the start of simulation. Subroutine ETEX computes subsequent changes in forage amounts. Comparable routines applicable to other localities can be added as equations and constants become available.

Subroutine TREE

Subroutine TREE is called by the main program and subroutines THNTR, START, REMOV, or REGEN whenever volume, growth, or mortality of tree stands is computed. Purpose of TREE is similar to that of UNDR, described above. The present version of TIMHAB contains two subroutines that apply to loblolly pine plantations in east Texas and Louisiana. Subroutine LOBPL contains equations for loblolly pine and is called when species code 1 appears on the appropriate data card. Subroutine HRDWD, called by species code 2, contains equations and constants for hardwoods growing in loblolly pine plantations.

Subroutine CHEK

CHEK is called by the main program each week or month of the simulation period. Current stand age of each subunit, plus the random amount computed in START, is compared with scheduled times of prescribed burning, thinning, and regeneration cutting to see if one of these operations is to be performed. Prescribed burning costs are added to total expenditures for the year in CHEK. One of the cutting subroutines (THNTR, REGEN, REMOV) is called by CHEK whenever a thinning or regeneration cutting is to be executed.

Thinnings will be made as frequently as specified by the program user, and options include not thinning during the rotation. Basal areas to be reserved after initial and subsequent thinnings are determined by the user.

Four regeneration methods may be specified: (1) clearcutting and planting, (2) seed-tree method, (3) two-cut shelterwood, and (4) three-cut shelterwood. More than one method may be used on a planning unit by assigning stands to be regenerated by the same method to the same working group. Three working groups may be designated for pine stands. Working group 4 must be reserved for hardwood stands.

Subroutine FOOD

For each week or month of every year, FOOD is called by the main program to compute potential deer-days of use available from each subunit. Potentials are based on the yield of preferred foods and on the following estimated daily nutritional requirements (ovendry basis) for growth of a 100-pound white-tailed deer: (1) 1.8 pounds of digestible dry matter, (2) 6,300 Kcals of gross energy, (3) 0.016 pound of phosphorus, and (4) 0.54 pound of crude protein (French and others 1955, Magruder and others 1957, Dietz 1971, Verme and Ullrey 1972).

The present version of TIMHAB uses only the estimated daily requirements listed above. Subroutine FOOD can be expanded readily to use values that reflect seasonal changes in requirements, as the information becomes available.

The first operation performed by FOOD is to define the period of use of each class of food (Short 1971, Harlow and Hooper

1972). Deer food of any class present during its season of non-use is excluded from carrying-capacity calculations.

Subsequent operations are performed separately for each subunit to account for the effect of recent cutting or prescribed burning. Calculations are made for available digestible dry matter, crude protein, phosphorus, and gross energy. The operations, of which the first seven are repeated for each subunit, are as follows:

1. Reduction of available food in the interior of large openings to account for non-use by deer, if this option is specified by the user.
2. Reduction of preferred browse leaves by 50 percent so the photosynthetic surface needed to keep the shrubs healthy will not be included in forage available for deer.
3. Computation of the nutrients and energy contributed by acorns, if present (Prosser and Brown 1966, Short 1971, Short 1975).
4. Computation of the nutrients and energy contributed by mushrooms and soft mast. Separate factors from a pending publication by Blair and others [1] are used for each of the four seasons of the year.
5. Computation of the nutrients and energy contributed by accessible preferred herbage and browse. Separate factors are used each season for forbs, grasses and grass-likes, browse leaves, and browse twigs (Short and others 1975, Blair and others [1]).
6. Computation of changes in the nutrient and energy content of herbaceous vegetation seasonally in the first 2 years after a burn (Halls and others 1952).
7. Adjustment, by season, in the nutrient and energy content of browse during the first and second years after a prescribed burn (Lay 1957).
8. Computation of the deer days of use per acre potentially available on the planning unit for the time period being simulated.

[1] Blair, R. M., H. L. Short, and E. A. Epps, Jr. Seasonal nutrient yield and digestibility of forage from a young pine plantation. Manuscript in preparation.

Nutrient and energy factors referred to above are also used in computing the contributions of forage in a clearcut. Separate factors for clearcuts can be added to the program, when available, if future research indicates this is necessary. Appropriate transfers of control to incorporate separate factors for clearcuts, if needed, are provided and identified by comment statements.

Subroutine SUMRY1

SUMRY1 is called by the main program at the end of each year simulated. It performs the following operations for each subunit of the planning unit:

1. Computes the volume and value of the timber growing stock at the end of the year. Sawlog volume of each subunit is added to board-foot total if it equals or exceeds minimum commercial board-foot limits. Non-sawlog parts of each stand are included in cubic volumes. Sawlog volumes below the specified minimum are assigned to cubic volume if both minimum cubic-foot limits and minimum age for inclusion in growing stock have been reached.
2. Computes the current value of any commercial cuts made during the year. The sum of these values less costs is the net income for the year; net income plus value of growing stock is reported as net worth.
3. Increases unit costs and prices by percentages specified by the program user. At the user's option, the 10 cost and price values may be held constant.
4. Computes acres required per deer for each of four measures of nutrients, based on values from subroutine FOOD. Values for the planning unit are compiled by week or month for each year.
5. Prints, for each week or month, available deer-days of use per acre and acres required per deer to supply needed quantities of digestible dry matter, crude protein, phosphorus, and gross energy. A separate page (two, if time period is 1 week) is

printed each year of the simulation period.

Subroutine SUMRY2

SUMRY2 is called by the main program after all years of the period are simulated. It computes values needed, in addition to initial growing stock value, to determine the internal rate of return from the timber operation. These values are (1) summations of the volumes cut annually and of their values, (2) a table of compound interest discount factors for rates from 1.0 to 15.5 percent for each year simulated, (3) discounted values of annual costs and returns and of the final value of the timber growing stock, and (4) present worth of net earnings (including increases in growing stock) of the timber operation at each discount rate from 1.0 to 15.5 percent.

As mentioned in the introduction, income from the sale of hunting privileges is not now included in this summary analysis.

Subroutine FINAL

FINAL is the last subroutine called by the main program. It writes four pages summarizing timber operations during the simulation period. The first page (numbered 11 in the Appendix) presents the cubic- and board-foot volumes and values of pines and hardwoods harvested each year. The second page records the volume and value of the pine and hardwood growing stock at the end of each year simulated. The third page shows operating cost, gross and net income, value of growing stock, and net worth for each year of the period. The last page of the simulation record shows the present values at each discount rate of the items computed in subroutine SUMRY2. The entries in the column headed "net present worth" are the discounted values of all periodic net income, including net increases in growing stock but excluding the value of the original growing stock. These values are used to determine the rate earned on the growing stock investment during the simulation period.

Subroutine THNTR

THNTR is called by subroutine CHEK to simulate thinnings to standards prescribed by the program user. This simulation requires performance of the following operations, each of which involves a call to TREE:

1. Computation of volumes before and after thinning and of the volume removed.
2. Reduction of the number of trees per acre as a result of thinning and corresponding changes in other stand variables.
3. Addition of volumes removed to cubic- or board-foot totals. Cuts are treated as harvests of board feet plus additional cubic volume if board-foot volume equals or exceeds minimum commercial limits per acre. Harvested volumes are added to cubic-foot totals if they cannot be classed as commercial sawlog cuts and if commercial standards for cubic volumes are reached.
4. Addition of returns from commercial thinnings to total income for the year. Cost of a noncommercial thinning is added to total expenses for the year. Administrative and other costs per 100 cubic feet or per 1,000 board feet are added to annual expenses.
5. Removal of midstory hardwoods during the thinning of pine stands, unless hardwoods are to be left uncut.

Subroutine REGEN

REGEN is called by subroutine CHEK to simulate clearcutting and planting and the final cuts of the shelterwood or seed-tree methods. The following operations are performed:

1. Computes volume removed and its value. Volumes are assigned to board or cubic feet as in subroutine THNTR. Stumpage income and sale costs are added to annual totals of income and costs.
2. Simulates clearcutting and planting. Average d.b.h. and other variables describing the rotation-age stand and the understory are reduced to zero. The stand is assigned a new number of trees per acre equal to the planting density selected by the program

user. Stand age is set to a negative value sufficient to insure a minimum of 9 months' delay between cutting and replanting for control of pales weevil (Hylobius pales Herbst.). Cost of planting is assigned to the year of cutting or to the following year, depending on when the delay period ends. Number of years since burning is set to zero if site preparation includes burning. Hardwoods may be reserved if desired.

3. Simulates final cuts of the seed-tree or shelterwood methods. Values of understory variables are assigned to equivalent overstory variables, and the understory variables are given values of zero.

Subroutine REMOV

REMOV is called by subroutine CHEK to simulate removal (partial) cuts of the seed-tree and shelterwood methods. It computes commercial board- and cubic-foot volumes removed, costs, and returns as does subroutine THNTR. Average d.b.h. and other variables describing the residual seed trees or shelterwood are computed as for intermediate thinnings. Subroutine TREE is called to initiate these computations.

A new seedling stand is established after each removal cut. Average age of the reproduction depends on the number of removal cuts made and on the length of the interval between them. Number of pine seedlings established per acre is specified by the program user. The number should be based on local experience with the regeneration method being simulated.

Subroutine ETEX

ETEX contains species-specific equations and constants used to compute seasonal increases and decreases of understory vegetation and the production of acorns and other fruits. It is applicable to species and conditions in the loblolly pine plantations of east Texas and Louisiana. ETEX consists of 12 parts, called individually by the main program except as noted below. Purpose and content of each of the 12 parts are as follows:

Part 1—to compute the ovendry weights of grasses and forbs produced on a subunit. Production in plantations aged 7 years or more is computed from total basal area of the overstory and midstory (Halls and Schuster 1965). Weights of grasses and forbs produced after clearcutting and site preparation but before planting are determined in Part 11.

Production in a plantation less than 7 years old is computed from plantation age. Data used to obtain the equations came from Stand 6, Stephen F. Austin Experimental Forest, Texas. The equation for forbs is

$$\text{Log}_e Y = 7.51238 - 0.54305A \qquad R = 0.969$$

where Y = pounds of ovendry forbs per acre
A = plantation age.

The equation for grasses is

$$\text{Log}_e Y = 7.68388 - 0.34197A \qquad R = 0.986$$

where: Y = pounds of ovendry grass per acre
A = plantation age.

Weight of herbage on each subunit is increased an appropriate amount if the area was prescribed burned within the previous 3 years (Lay 1956). Part 12 of ETEX is called to reduce the amount of herbage to zero if burning takes place during the current week or month.

Part 2--to reduce the grasses and forbs on each subunit during the winter months. In the absence of research data, a percentage of the amount present at the end of the previous week or month is subtracted from every subunit total during each period of the non-growing season.

Part 3--to compute the ovendry weight of berries and other soft mast produced on a subunit. Production on a subunit not recently prescribed burned is computed from total overstory and midstory basal area with an equation by Hastings (1966). Production is set to zero during the first year after a prescribed burn. It is reduced below the amount given by Hastings' equation during the following 2 years (Lay

1956). No reduction is made soon after partial cutting because necessary information is lacking. Statements have been provided in ETEX to permit inclusion of the effects of partial cutting when research results become available.

Part 4--to compute the reduction of soft mast due to decay, as described for grasses and forbs in Part 2.

Part 5—to compute the ovendry weights of browse leaves and twigs produced on a subunit. In plantations aged 7 years or more, production is computed from two variables—overstory and midstory basal areas (Blair 1967). In plantations less than 7 years old, production (high- and medium-preference species only) is calculated from the following equations based on data from the Stephen F. Austin Experimental Forest, Texas:

$$Y = 353.3714 + 50.8061A^2 \qquad R = 0.988$$
$$\text{Log}_e Y = 7.77840 - 0.36945AG \qquad R=0.989$$

where:

Y = pounds of ovendry browse per acre.
A = plantation age if less than 3 years.
AG = plantation age from 3 to 7 years.

Browse production is reduced to zero in the first week or month after prescribed burning. It increases from 44 to 94 percent of the amount in unburned stands over the following 3 years (Lay 1956).

Available information is inadequate to estimate browse losses due to partial cutting of the overstory. Provision has been made in ETEX for future inclusion of the appropriate statements. Production after clearcutting and site preparation but before plantation establishment is computed in Part 11.

Unpublished constants obtained by R. M. Blair, Southern Forest Experiment Station, are used to reduce total weight of browse to that of high- and medium-preference species only. Other constants from Blair subdivide total preferred browse into the weights of leaves and twigs. Separate constants are available for subunits with and without a midstory.

Part 6—to reduce the browse leaves on each subunit during the winter months. Computations parallel those described for Part 2. After autumn leaf abscission, leaf weight drops sharply until it approximates the average amount of nonconifer, evergreen browse leaves present.

Part 7—to compute the ovendry weight of acorns available on a subunit if oaks of acorn-bearing size are present. The equations in ETEX are mathematical expressions of production per square foot of basal area, by diameter classes for selected species, from a table published by Goodrum and others (1971). Amounts computed exclude quantities eaten by arboral feeders and allow 21 percent for losses to weevils.

The percentage of the acorn crop available to deer during any week or month of the autumn and winter is based on 8 years' record of catch in seed traps on the Stephen F. Austin Experimental Forest, Texas.

Part 8--to set the amount of acorns present to zero during the period of nonavailability.

Part 9--to compute the ovendry weight of mushrooms produced on each subunit. Preliminary seasonal yields obtained by R. M. Blair are included in ETEX. Work is underway to obtain more detailed information.

Part 10--to compute rates of change used in other parts of ETEX. Each rate is the dx/dt used in the Euler solution of the production equations. This part is called once by subroutine START at the beginning of simulation.

Part 11--to compute the ovendry weight of forbs, grasses, and browse on clearcuts not yet replanted to trees. Production per acre is estimated for five means of site preparation : (1) none, (2) burning and discing, (3) KG blade, (4) chopping, and (5) burning (Stransky 1976). Constants provided by R. M. Blair divide total browse into weights of leaves and of twigs.

Part 12—to reduce the weight of herbage and browse on a subunit to zero immediately after a burn, as called for by other parts of ETEX.

Subroutine ETXBEG

ETXBEG is called by subroutine START as part of the determination of initial conditions on the planning unit. It contains most of the equations and constants found in subroutine ETEX and provides the same alternative computations for prescribed burning and clearcutting. The two subroutines differ in that the computations in ETXBEG estimate the forage present on January 1 of the first year of the simulation period. Separate computations are made for the forbs, grasses, soft mast, and browse on each subunit. Mushrooms and acorns are not computed in ETXBEG but are computed in ETEX as the simulation period begins.

Subroutine LOBPL

Subroutine LOBPLis called by subroutine TREE whenever an equation applicable to the overstory of loblolly pine plantations is needed. Like ETEX, subroutine LOBPL consists of several parts, each of which may be called independently. The equations and constants in the 10 parts of LOBPL are described elsewhere (Myers 1977). Briefly, they consist of the following:

1. An equation for basal area growth as a function of current basal area, stand age, and site index (Clutter 1963).
2. Equations for estimating average dominant and codominat height from stand age and site index (Lenhart 1972, Farrar 1973).
3. Initial average d.b.h. of young stands as a function of initial density, age, and site index.
4. Merchantable cubic-foot volumes inside bark per acre in trees 5 inches in d.b.h. and larger to a 4-inch top. Volumes are computed from average d.b.h., height, and basal area.
5. Board-foot volumes per acre in trees 9 inches in d.b.h. and larger to a 7-inch top. Volumes are based on the Scribner Rule and are obtained from cubic-volumes and ratios of board feet per cubic foot.

6-8. Changes in average stand d.b.h., average dominant and codominant height, and number of trees per acre resulting immediately from partial cuttings.

9. Noncatastrophic mortality in unthinned stands as a function of stand age, initial density, and height (Smalley and Bailey 1974).
10. Noncatastrophic mortality in previously-thinned stands from average stand d.b.h.

Subroutine HRDWD

HRDWD is called by TREE whenever growth or mortality of the hardwood midstory is calculated. It has 10 independent parts arranged in the same sequence as LOBPL. Several of the parts, however, are not required for proper execution of program TIMHAB. This structure of subroutine HRDWD is used to permit computation of overstory and midstory values in the same loops. The parts of HRDWD essential for midstory computations are as follows:

Part 1—to compute the increase in average d.b.h. of the midstory. Annual increases in d.b.h. of 0.12 to 0.20 inch reflect both growth in d.b.h. and increase in the number of stems more than 4.5 feet tall.

Part 3—to determine the initial average d.b.h. of young midstories when they reach an average height of 4.5 feet.

Parts 5, 6, 7—to assign age and other stand values to the future midstory after removal of the previous midstory during thinning or regeneration of pine stands. The three parts contain the same FORTRAN statements. Most variables describing the midstory are assigned values of zero. Age is set at -2.0 years and density at 80.0 stems per acre, thus estimating 80 stems taller than 4.5 feet 2 years after cutting.

Part 10—to change the number of midstory stems per acre. The equation, based on the data used for Part 1, reflects the combined effect of noncatastrophic mortality and any increase in the number of stems more than 4.5 feet tall. Numbers increase for a number of years and then decline. Rate of change and the stand age at time of first decline vary with total overstory and midstory basal area.

Constants and equations describing midstory changes are based on limited data from one locality (Alexander State Forest, Louisiana) that were obtained by R. M. Blair for another purpose. Research on the development of hardwood midstories should be a high priority item for those interested in multiple use of Southern forests.

USER-SUPPLIED INFORMATION

Persons using program TIMHAB must supply values of 124 variables on data cards (table 1). Ninety-six of the variables describe management decisions and control program execution. One set of the other 28 variables is needed for each planning subunit to be simulated.

Data cards are identified in table 1 by type numbers that, except for subunit information, show their sequence in the data deck. A data deck will consist of (1) one card each of types 1 to 3; (2) four cards of type 4 in the sequence 1, 2, 3, 4 for working groups 1, 2, 3, and 4; (3) one card each of card types 5 and 6; (4) one card each of types 7 and 8 for each subunit, and (5) one card of type 9.

Card types 7 and 8 are read for one subunit before reading begins for the next subunit. Sequence of these cards is therefore 7, 8, 7, 8, etc., until the required number has been read.

Timber Operations

Data card type 4 has values that control intermediate and regeneration cuts, summations of commercial volumes, planting, and prescribed burning.

Five variables, columns 17 through 36, control execution of regeneration cuts and determine the regeneration method to be simulated. For clearcutting, age at first regeneration cut is entered on card 4, and the other regeneration variables are left blank or given values of zero. Seed-tree cutting and two-cut shelterwood require nonzero values for the first three regeneration variables: REGN(L, 1)--stand age at first cutting; REGN(L, 2)--age at seed-tree or shelterwood removal; and VLLV(L, 1)--basal area to be left as a seed source at age REGN(L, 1). Three-cut shelterwood requires that all five regeneration variables be assigned values larger than zero.

Regardless of regeneration method, the age of first regeneration cut, columns 17 to 20, must never be assigned a value of zero if any subunits are assigned to that working group.

Thinnings and prescribed burnings are scheduled by variables in columns 1 through 16 and 49 through 56 on card type 4. The first treatment will occur or is assumed to have occurred at a stand age of THN1(L) or BURN(L). Subsequent thinnings and burnings will be simulated at intervals of CYCL(L) or BRNCY(L) years.

Midstory Retention

The hardwood midstory may be either removed or retained when pine stands are thinned or regenerated. Midstories of a working group are retained if DECID(L) is assigned a nonzero value on card type 4. Otherwise, they will be removed. Variable HDAGE(L) is used to indicate the age at which reserved midstory trees will be removed some time in the future. This option is provided to show how wood production and deer food supply are affected by retaining hardwoods during the thinning of a pine overstory.

Working Group Assignments

Four cards of data card type 4 are needed in the data deck, one for each of the four possible working groups to which stands of the planning unit can be assigned. A working group consists of all stands for which rotation length and other variables on card type 4 are equal. Cards of type 4 are arranged in the order working group 1, 2, 3, and 4 in the data deck.

Working group 1 must be one of the working groups established for the planning

Table 1.—*Order and contents of the data deck.*

Card type	Variable name	Punch card columns	Format	Description of variable
1	FORET(N)	1-24	6A4	Name of forest, block, or tract in which planning unit is located.
2	NYR	1-2	I2	Number of years to be simulated.
	INVL	3-7	A5	Time period for which each computation of change is made. Enter "WEEK" or "MONTH," left justified. Will be read as A4 format.
	DESCR(N)	8-79	18A4	Name, location, or other description of the planning unit simulated.
3	ITR1	1-3	I3	Week or month when tree growth starts. Enter number from 1-12 if INVL is "MONTH" and from 1-52 if INVL is "WEEK."
	ITR2	4-6	I3	Week or month when tree growth ends. Same code as for ITR1.
	IHB1	7-9	I3	Week or month when herbaceous growth starts. Same code as for ITR1.
	IHB2	10-12	I3	Week or month when herbaceous growth ends. Same code as for ITR1.
	ISH1	13-15	I3	Week or month when growth of shrubs and small understory hardwoods starts. Same code as for ITR1.
	ISH2	16-18	I3	Week or month when growth of shrubs and small understory hardwoods ends. Same code as for ITR1.
	IAC1	19-21	I3	Week or month when acorns first become available to deer. Same code as for ITR1.
	IAC2	22-24	I3	Last week or month when acorns are available to deer. Same code as for ITR1.
	MST1	25-27	I3	Week or month when berries and other fruits become available to deer. Same code as for ITR1.
	MST2	28-30	I3	Last week or month when berries and other fruits are available to deer. Same code as for ITR1.
4	THN1(L)	1-4	F4.0	Stand age when first thinning, if any, is made. Set equal to rotation length if no thinnings will be made.
(need	THIN(L)	5-8	F4.0	Basal area in square feet to be left after initial thinning.
four	DLEV(L)	9-12	F4.0	Basal area to be left in partial cuts after the first.
cards)	CYCL(L)	13-16	F4.0	Number of years between scheduled thinnings. Set equal to rotation length if no thinnings will be made.
	REGN(L,1)	17-20	F4.0	Stand age when first regeneration cut is made. Must never equal zero. This is the age for clearcutting if following regeneration variables have values of zero.
	VLLV(L,1)	21-24	F4.0	Basal area to be left at age REGN(1). Will be zero for clearcutting.

Table 1.—*continued*

Card type	Variable name	Punch card columns	Format	Description of variable
	REGN(L,2)	25-28	F4.0	Stand age at which second regeneration cut, if any, will occur. Age for removal of seed trees or second cut of shelterwood.
4	VLLV(L,2)	29-32	F4.0	Basal area to be left at age REGN(2). Will be zero except for three-cut shelterwood.
	REGN(L,3)	33-36	F4.0	Stand age at which third regeneration cut, if any, will occur. Final cut of three-cut shelterwood.
	COMBF(L)	37-40	F4.1	Minimum commercial cut in thousands of board feet per acre.
	COMCU(L)	41-44	F4.1	Minimum commercial cut in hundreds of cubic feet per acre.
	PLNT(L)	45-48	F4.0	Number of trees to be planted per acre. Also number of established seedlings expected from seed trees or shelterwood.
	BURN(L)	49-52	F4.0	Stand age at time of initial prescribed burning.
	BRNCY(L)	53-56	F4.0	Number of years between prescribed burnings.
	SDAGE(L)	57-60	F4.0	Age of planting stock at time of transplanting to the planning unit.
	DECID(L)	61-64	F4.0	Instructions to save (DECID=1) or cut (DECID=0) midstory hardwoods when overstory pine is thinned or regenerated.
	HDAGE(L)	65-68	F4.0	Age at which midstory hardwoods will be cut. Needed only if DECID(L) has a nonzero value.
5	AGMRCH	1-5	F5.0	Minimum stand age for volume to be included in summations of growing stock.
	BFPIN	6-10	F5.2	Stumpage value of 1,000 board feet of pine.
	CUPIN	11-15	F5.2	Stumpage value of 100 cubic feet of pine.
	BFHWD	16-20	F5.2	Average stumpage value of 1,000 board feet of hardwoods.
	CUHWD	21-25	F5.2	Average stumpage value of 100 cubic feet of hardwoods.
	CHGPR	26-30	F5.2	Percentage increase in stumpage prices annually. Enter zero for constant prices.
	CPLT	31-35	F5.2	Planting cost per acre, including site preparation.
	CTHN	36-40	F5.2	Cost per acre of a precommercial thinning.
	CBRN	41-45	F5.2	Cost per acre of periodic prescribed burning, not including burning for site preparation.
	ACCST	46-50	F5.2	Annual costs per acre for taxes, protection, supervision, etc.
	CUCST	51-55	F5.2	Cost of marking, supervision, etc. for each 100 cubic feet harvested.
	BFCST	56-60	F5.2	Cost of marking, supervision, etc. for each 1,000 board feet harvested.
	CHGCS	61-65	F5.2	Percentage increase in costs annually. Enter zero for constant costs.

Table 1.—*continued*

Card type	Variable name	Punch card columns	Format	Description of variable
6	ENTRY	1-4	F4.0	Distance (in feet) from uncut edge that a white-tailed deer will enter a clearcut or a plantation less than 3 years old. Enter zero if area option is not wanted.
7	IPS(J)	1-3	I3	Identification number of the stand or planning subunit.
(one per sub-	ACRE(J)	4-8	F5.1	Area in acres of the subunit described on the card.
unit)	SITE(J)	9-12	F4.0	Site index of the subunit. Base age must be 50 years to match that used in the growth equations.
	MAC(J)	13-15	I3	Locality code number used to select the subroutine that contains constants and equations applicable to understories in the locality of the subunit. Only code 1, east Texas-Louisiana, is now available.
	STPRP(J)	16-18	F3.0	Site preparation treatment during regeneration. Code as 1 = do nothing, 2 = burning, 3 = chopping, 4 = KG blade, 5 = discing.
	IWGP(J)	19-21	I3	Working group assignment of the subunit. Working group 4 is reserved for hardwood stands.
	NABR1(J)	22-24	I3	Identification number of the subunit north of the subunit described. Enter zero if on north boundary or if area option not wanted.
	NABR2(J)	25-27	I3	Identification number of the subunit east of the subunit described. Enter zero if on east boundary or if area option not wanted.
	NABR3(J)	28-30	I3	Identification number of the subunit south of the subunit described. Enter zero if on south boundary or if area option not wanted.
	NABR4(J)	31-33	I3	Identification number of the subunit west of the subunit described. Enter zero if on west boundary or if area option not wanted.
	YRCUT(J)	34-37	F4.2	Number of years since a partial or regeneration cut was made on the subunit.
	YRBRN(J)	38-41	F4.2	Number of years since a prescribed burn was made on the subunit.
8	IPS(J)	1-3	I3	Identification number of the stand or planning subunit.
(one per sub-unit)	KAK(1,J)	4-6	I3	Identification number of the species composing the overstory. Limited at present to code 1, loblolly pine.
	DBH(1,J)	7-9	F3.1	Average d.b.h. (inches) of all live trees in the overstory stand.
	HT(1,J)	10-12	F3.0	Average height (feet) of dominant and codominant trees of the overstory.
	DEN(1,J)	13-17	F5.0	Number of live trees in the overstory. Enter value of PLNT if there are no trees present

Table 1.—*continued*

Card type	Variable name	Punch card columns	Format	Description of variable
				but area will be planted some time in the future.
	AGE(1,J)	18-20	F3.0	Age of the overstory. Include seedling age if the subunit is a plantation. For future planting of a treeless subunit, enter a negative value equal to the number of years' delay.
8	KAK(2,J)	21-23	I3	Identification number of the species composing the regeneration under seed trees or a shelterwood. Limited at present to code 1, loblolly pine.
	DBH(2,J)	24-26	F3.1	Average d.b.h. of the regeneration under seed trees or shelterwood, if any.
	HT(2,J)	27-29	F3.0	Average height of potential dominants and codominants of the regeneration.
	DEN(2,J)	30-34	F5.0	Number of live trees in the regeneration under seed trees or a shelterwood.
	AGE(2,J)	35-37	F3.0	Age of the regeneration under seed trees or a shelterwood.
	KAK(3,J)	38-40	I3	Identification number used to select the subroutine containing equations and constants for a hardwood midstory in pine stands. Must be entered even though no hardwoods now present. Limited at present to code 2.
	DBH(3,J)	41-43	F3.1	Average d.b.h. of the hardwood midstory if subunit is a pine stand.
	HT(3,J)	44-46	F3.0	Average height of midstory hardwoods if subunit is a pine stand.
	DEN(3,J)	47-51	F5.0	Average number of midstory hardwoods per acre if subunit is a pine stand.
	AGE(3,J)	52-54	F3.0	Average age of midstory hardwoods if subunit is a pine stand.
	PCTOAK(J)	55-57	F3.0	Percentage of hardwood basal area that is oak. Enter actual percentage or average percentage for the locality even if hardwoods not now present. Base percentage on hardwood overstory if IWGP equals 4.
9	(Punch zero in column 3)			

unit to prevent termination of execution by subroutine ERROR. Working group 4 is reserved for hardwood (not midstory) stands. No assignments may be made to that working group until a subroutine for hardwood stands equivalent to LOBPL has been added to the program.

Each subunit or stand is assigned to a working group by variable IWGP(J) on data card type 7.

Stand Variables

Stand descriptions on data card type 8 apply to conditions just before the simulation period starts on January 1 of simulation year one. Variables in columns 4 through 20 report conditions in the overstory, which at present must be loblolly pine, species 1. Subroutines for other pines may be added when developed. The values punched in columns 21 to 37 describe seedlings under seed trees or a shelterwood. Values are not assigned to this set of variables if seedlings are not present. Variables in columns 38 through 54 apply to the hardwood midstory, if any, in pine stands. Species identification number 2 (to call subroutine HRDWD) must be punched even if the subunit was just burned or prepared for planting. The number will be used in computations of future growth after resprouting.

Subunit Size

Reductions in food availability due to large regeneration areas may be simulated by assigning an appropriate value to ENTRY on data card type 6. ENTRY is the distance (in feet) from a timber edge that a white-tailed deer will enter a clearcut or a plantation less than 3 years old to utilize food there. A checkerboard arrangement of subunits is assumed, although uniformity of subunit size may be ignored if adjacent subunits will bear trees more than 3 years old throughout the simulation period. This option is selected by assigning a nonzero value to ENTRY and entering the identification numbers of adjacent subunits on data card type 7. Punch a zero for ENTRY on card type 6 if the option is not wanted.

Time Intervals

Unit time interval for the simulation may be either 1 week or 1 month. The choice is made on data card type 2. Deer-days of use and acres per deer will be computed for either interval. Simulation intervals of 1 month are appropriate for most computer runs and for the level of precision of the equations and constants currently in TIMHAB.

MODIFICATION OF TIMHAB

TIMHAB can be readily modified to meet the needs of a variety of users. Several possible changes are described below.

Equations and constants now in the program should be replaced by improved versions whenever they become available. All candidates for replacement are in subroutines FOOD, ETEX, ETXBEG, LOBPL, and HRDWD. FOOD contains the four daily nutrition requirements used in TIMHAB and defines the period of use of each food class. It also has the constants that convert ovendry weights of the various food classes to digestible dry matter, crude protein, phosphorus, and gross energy. ETEX and ETXBEG contain constants and equations for acorns and understories. LOBPL performs all computations for pine overstories; HRDWD has the items needed for hardwood midstories.

A change in subroutine FOOD that redefines the period of use of any food requires a corresponding change at the end of subroutine BEGIN. This change is needed to correct the record on the second of the two pages printed by BEGIN that report conditions before simulation starts (Appendix).

Additional subroutines can be included in TIMHAB to provide equations for other species or conditions. New subroutines for understories must follow the sequence used in ETEX and ETXBEG. CONTINUE statements in subroutine UNDR are replaced by CALL statements for the new routines. New subroutines for trees must follow the order of computations in LOBPL or HRDWD. Statements calling them are placed in subroutine TREE. In both UNDR and TREE, order of the call statement labels in each "GO TO" determine the identification number of the locality or species added.

Simulation periods of more than 50 years require changes in (1) dimensions in the common blocks and a DIMENSION statement in SUMRY2 and (2) one DO statement each in INIT and SUMRY2.

Simulation of conditions on more than 200 subunits requires changes in (1) dimensions in the common blocks, (2) two DO statements in subroutine INIT, and (3) one DO statement each in BASIS and START.

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APPENDIX

SAMPLE OUTPUT

CONDITIONS AT START OF SIMULATION

UNIT= BOWIE TRACT. TOTAL AREA OF UNIT= 6819.0

SIMULATION SITUATION= TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

NUMBER OF INVENTORY RECORDS READ= 60 NUMBER OF INVENTORY RECORDS PROCESSED= 60

TIME UNITS PER YEAR= 12

STUMPAGE VALUES=	
PINE	
CUBIC FEET	7.85
BOARD FEET	109.00
HARDWOODS	
CUBIC FEET	3.15
BOARD FEET	24.40

- - - - - - - - TIMBER VOLUMES AND VALUE, TOTALS FOR PLANNING UNIT - - - - - - - -

	PINE	HARDWOODS	TOTALS
HUNDREDS OF CUBIC FEET	60396.13	.00	60396.13
THOUSANDS OF BOARD FEET	35095.43	.00	35095.43
VALUE OF CU. FT., DOLLARS	474109.	0.	474109.
VALUE OF BD. FT., DOLLARS	3825396.	0.	3825396.
TOTAL VALUE, DOLLARS	4299505.	0.	4299505.

MINIMUM AGE FOR INCLUSION OF VOLUME IN GROWING STOCK= 10. YEARS.

MINIMUM VOLUME INCLUDED EQUALS MINIMUM COMMERCIAL LIMITS.

- - - MANAGEMENT SITUATION BY WORKING GROUP - - -

	WG1	WG2	WG3	WG4
AGE AT FIRST THINNING, YEARS	21.0	30.0	.0	.0
INITIAL THINNING LEVEL, SQ. FT.	80.0	80.0	.0	.0
SUBSEQUENT THINNING LEVEL, SQ. FT.	90.0	90.0	.0	.0
MINIMUM CUT, M BOARD FEET	2.0	30.0	.0	.0
MINIMUM CUT, 100 CUBIC FEET	3.5	3.5	.0	.0
THINNING INTERVAL, YEARS	7.0	30.0	.0	.0
AGE AT FIRST REGEN CUT, YEARS	70.0	30.0	.0	.0
AGE AT SECOND REGEN CUT, YEARS	.0	.0	.0	.0
AGE AT THIRD REGEN CUT, YEARS	.0	.0	.0	.0
AGE AT FIRST PRESC. BURN, YEARS	22.0	30.0	.0	.0
PRESCRIBED BURNING INTERVAL, YEARS	7.0	30.0	.0	.0
TOTAL AREA, ACRES	3249.8	3569.2	.0	.0

CONDITIONS AT START OF SIMULATION

PAGE 2

UNIT- BOWIE TRACT.　　　　TOTAL AREA OF UNIT- 6819.0

SIMULATION SITUATION- TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

INITIAL COSTS OF OPERATIONS, PER ACRE-

PLANTING	80.00
THINNING	41.00
BURNING	7.00
PER CUNIT CUT	1.36
PER MBF CUT	2.70
FIXED COSTS	.80

ANNUAL INCREASES, IN PERCENT-

COSTS	3.00
VALUES	3.00

PERIOD OF USE OF VARIOUS CLASSES OF FOODS

ACORNS - SEPTEMBER TO FEBRUARY, INCLUSIVE.
BROWSE LEAVES - YEAR-LONG USE.
BROWSE TWIGS - MARCH TO MAY, INCLUSIVE.
FORBS - MARCH TO OCTOBER, INCLUSIVE.
GRASS AND GRASS-LIKE - DECEMBER TO MAY, INCLUSIVE.
MUSHROOMS - YEAR-LONG USE.
SOFT MAST - JUNE TO FEBRUARY, INCLUSIVE.

CONDITIONS AT END OF EACH YEAR

PAGE 1

UNIT= BOWIE TRACT.   TOTAL AREA OF UNIT= 6819.0

SIMULATION SITUATION= TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

STATUS OF DEER FOODS IN YEAR 1 OF THE SIMULATION

PERIOD OF YEAR	DEER DAYS OF USE PER ACRE: DIGESTIBLE DRY MATTER	CRUDE PROTEIN	PHOSPHORUS	GROSS ENERGY	ACRES PER DEER: DIGESTIBLE DRY MATTER	CRUDE PROTEIN	PHOSPHORUS	GROSS ENERGY
1	13.4	10.8	4.5	31.2	2.3	2.9	6.8	1.0
2	10.1	7.9	3.3	21.8	2.8	3.6	8.5	1.3
3	32.4	27.2	17.6	26.3	1.0	1.1	1.8	1.2
4	20.0	16.8	10.6	16.5	1.5	1.8	2.8	1.8
5	39.8	33.7	21.3	32.9	.8	.9	1.5	.9
6	24.2	13.2	6.4	24.0	1.2	2.3	4.7	1.2
7	32.2	17.6	8.5	32.0	1.0	1.8	3.6	1.0
8	40.2	22.0	10.6	40.0	.8	1.4	2.9	.8
9	42.8	23.8	10.9	48.9	.7	1.3	2.8	.6
10	45.9	25.6	11.8	53.8	.7	1.2	2.6	.6
11	30.3	19.7	9.1	44.3	1.0	1.5	3.3	.7
12	16.3	13.1	5.5	37.6	1.9	2.4	5.6	.8

CONDITIONS AT END OF EACH YEAR

PAGE 10

UNIT= BONIE TRACT TOTAL AREA OF UNIT= 6819.0

SIMULATION SITUATION TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

STATUS OF DEER FOODS IN YEAR 10 OF THE SIMULATION

PERIOD OF YEAR	DEER DAYS OF USE PER ACRE: DIGESTIBLE DRY MATTER	CRUDE PROTEIN	PHOSPHORUS	GROSS ENERGY	ACRES PER DEER: DIGESTIBLE DRY MATTER	CRUDE PROTEIN	PHOSPHORUS	GROSS ENERGY
1	10.9	13.3	5.6	37.1	1.8	2.3	5.5	.8
2	13.2	10.0	4.2	26.4	2.1	2.8	6.7	1.1
3	53.2	41.8	28.2	41.6	.6	.7	1.1	.7
4	29.1	24.1	15.2	24.2	1.0	1.2	2.0	1.2
5	57.1	47.0	29.6	47.3	.5	.7	1.0	.7
6	34.6	19.0	9.2	34.7	.9	1.6	3.3	.9
7	45.7	25.0	12.1	45.7	.7	1.2	2.6	.7
8	56.5	30.9	14.9	56.6	.5	1.0	2.1	.5
9	59.7	33.0	15.1	68.7	.5	.9	2.0	.4
10	64.5	35.7	16.4	75.8	.5	.9	1.9	.4
11	40.2	26.0	12.1	58.8	.7	1.2	2.5	.5
12	21.7	17.4	7.4	50.0	1.4	1.8	4.2	.6

CONDITIONS AT END OF EACH YEAR

UNIT= BOWIE TRACT. TOTAL AREA OF UNIT= 6819.0

SIMULATION SITUATION= TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

VOLUMES HARVESTED AND VALUES

	PINES			HARDWOODS		
YEAR	CU. FT.	MBF	VALUE	CU. FT.	MBF	VALUE
1	8617.	2218.	309403.	0.	0.	0.
2	362.	1770.	201611.	0.	0.	0.
3	8442.	574.	136644.	0.	0.	0.
4	3925.	0.	33669.	0.	0.	0.
5	4620.	2820.	386752.	0.	0.	0.
6	4304.	228.	67971.	0.	0.	0.
7	3822.	1815.	272057.	0.	0.	0.
8	4099.	1342.	219504.	0.	0.	0.
9	3745.	619.	122665.	0.	0.	0.
10	4362.	3686.	568897.	0.	0.	0.
TOTAL	46299.	15071.	2319172.	0.	0.	0.

CONDITIONS AT END OF EACH YEAR

PAGE 12

UNIT= BOWIE TRACT. TOTAL AREA OF UNIT= 6819.0

SIMULATION SITUATION= TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

GROWING STOCK VOLUMES, AND VALUES

YEAR	PINES CU. FT.	PINES MBF	PINES VALUE	HARDWOODS CU. FT.	HARDWOODS MBF	HARDWOODS VALUE
1	55135.	34690.	4214011.	0.	0.	0.
2	59709.	34414.	4346412.	0.	0.	0.
3	55472.	35551.	4573015.	0.	0.	0.
4	55609.	37298.	4919484.	0.	0.	0.
5	55238.	35912.	4893705.	0.	0.	0.
6	55704.	37169.	5203584.	0.	0.	0.
7	56221.	36772.	5312922.	0.	0.	0.
8	56228.	37158.	5524104.	0.	0.	0.
9	56005.	38571.	5882736.	0.	0.	0.
10	55568.	36604.	5774962.	0.	0.	0.

CONDITIONS AT END OF EACH YEAR

PAGE 13

UNIT= BOWIE TRACT. TOTAL AREA OF UNIT= 6819.0

SIMULATION SITUATION= TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

YEAR	ANNUAL COSTS	ANNUAL GAINS	NET INCOME	VALUE GROWING STOCK	TOTAL NET WORTH
1	34507.	309403.	274897.	4214011.	4488907.
2	45081.	201611.	156529.	4346412.	4502941.
3	34428.	136644.	102216.	4573015.	4675231.
4	43933.	33669.	-10264.	4919484.	4909219.
5	46651.	386752.	340102.	4893705.	5233806.
6	64876.	67971.	3095.	5203584.	5206678.
7	43548.	272057.	228509.	5312922.	5541430.
8	29606.	219504.	189898.	5524104.	5714002.
9	40919.	122665.	81746.	5882736.	5964481.
10	57545.	568897.	511352.	5774962.	6286314.
TOTAL	441094.	2319172.	1878077.		

PRESENT WORTH AND RATE EARNED

UNIT- BONIE TRACT. TOTAL AREA OF UNIT- 6819.0

SIMULATION SITUATION- TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

VALUE OF INITIAL GROWING STOCK--$ 4299505.

VALUES DISCOUNTED TO PRESENT (DOLLARS)

COMPOUND RATE (PERCENT)	FUTURE GROWING STOCK	ALL INCOMES	STOCK PLUS INCOMES	ALL COSTS	NET PRESENT WORTH
1.0	5228039.	2184613.	7412652.	416965.	2696182.
1.5	4976129.	2121568.	7097697.	405602.	2392590.
2.0	4737507.	2061163.	6798670.	394679.	2104486.
2.5	4511407.	2003262.	6514669.	384175.	1830989.
3.0	4297124.	1947745.	6244869.	374070.	1571293.
3.5	4093987.	1894495.	5988482.	364347.	1324630.
4.0	3901361.	1843400.	5744761.	354987.	1090269.
4.5	3718690.	1794364.	5513054.	345976.	867573.
5.0	3545352.	1747272.	5292624.	337295.	655824.
5.5	3380860.	1702036.	5082896.	328930.	454461.
6.0	3224725.	1658572.	4883297.	320867.	262924.
6.5	3076485.	1616793.	4693278.	313094.	80678.
7.0	2935708.	1576624.	4512332.	305597.	-92771.
7.5	2801983.	1537986.	4339969.	298365.	-257901.
8.0	2674929.	1500809.	4175738.	291385.	-415152.
8.5	2554206.	1465035.	4019241.	284648.	-564913.
9.0	2439427.	1430584.	3870011.	278142.	-707637.
9.5	2330295.	1397401.	3727696.	271858.	-843668.
10.0	2226507.	1365433.	3591940.	265786.	-973352.
10.5	2127784.	1334623.	3462407.	259918.	-1097017.
11.0	2033855.	1304921.	3338776.	254245.	-1214975.
11.5	1944469.	1276277.	3220746.	248759.	-1327518.
12.0	1859384.	1248645.	3108029.	243453.	-1434929.
12.5	1778391.	1221986.	3000377.	238319.	-1537448.
13.0	1701246.	1196248.	2897494.	233350.	-1635362.
13.5	1627770.	1171396.	2799166.	228540.	-1728879.
14.0	1557767.	1147391.	2705158.	223881.	-1818228.
14.5	1491062.	1124198.	2615260.	219369.	-1903614.
15.0	1427486.	1101784.	2529270.	214997.	-1985232.
15.5	1366880.	1080116.	2446996.	210760.	-2063270.

IDENTIFY RATE EARNED AT POINT WHERE NET WORTH EQUALS ZERO.

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Myers, Clifford A.
1977. Simulating timber and deer food potential in loblolly pine plantations. South. For. Exp. Stn., New Orleans, La. 29 p. (USDA For. Serv. Gen. Tech. Rep. SO-12)

This computer program analyzes both timber and deer food production on managed forests, providing estimates of the number of acres required per deer for each week or month, yearly timber cuts, and current timber growing stock, as well as a cost and return analysis of the timber operation. The program is applicable to loblolly pine plantations in east Texas and Louisiana but can be readily modified for other species or areas.

Additional keywords: Timber management, forest management, simulation, deer habitat potential, wildlife foods, deer management, *Pinus taeda*, *Odocoileus virginianus*.

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