FOREX - AN EXPERT SYSTEM FOR MANAGING EVEN-AGED UPLAND OAK FORESTS ON STEEP TERRAIN

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Abstract: An expert system, FOREX, was developed to access the data from the database management provided by MANAGE. For a specific site index, the user of FOREX can obtain information on present net worth, optimal thinning entry timing, optimal stand rotation age, diameter at breast height, volume by grade and value of the trees harvested, and based on the cable yarder used, the average slope yarding distance, truck class, road class, log-bucking methods, and the number of thinnings desired. This paper describes FOREX, which is valuable to forest managers, planners, loggers, and landowners, planning to harvest even-aged upland oak stands located on steep terrain.

INTRODUCTION

Commercial forest management involves making decisions regarding various activities that range from regeneration efforts to commercial logging operations. A rigorous financial evaluation must be performed. Decisionmakers must know which variables affect cost and profitability and understand how these variables interact for a particular harvesting operation. They must be able to determine the total volume, species, and individual size of hardwood logs that can be removed without incurring a loss. To evaluate the long-term costs and benefits of the harvesting and silvicultural treatments that form the chain of activities and yields in the life of a stand, a computer systems simulation model called MANAGE was developed (LeDoux 1986). MANAGE, a computer program written in FORTRAN V, is a combination of discrete and stochastic subroutines. The model allows the manager to evaluate how alternative harvesting technology, silvicultural treatments, market price, and economic combinations affect costs and benefits over the life of the stand.

The model input is a detailed individual user-specified tree list, and the output simulates stand growth based on some user-specified silvicultural treatment, harvest of desired volume or stems with the logging system specified, sale cost of the wood, and economic analysis for the respective treatment and entry. The process is repeated for user-specified alternative mixes of entry timing, logging equipment, silvicultural treatments, and economic conditions for the life of the stand in question. The results are stored by entry and life of the stand. Users can specify numerous management scenarios during the life of the stand and evaluate the outcomes.

MANAGE, although valuable, takes substantial computing time for each execution when run on personal computers. The calculation of present net worth (PNW) of an activity is based on a number of variables such as slope yarding distance, buck type, and road class. The user has to specify the values of these variables each time the program is run. It is impractical to run MANAGE for so many combinations. Moreover, it is very difficult for a novice to understand the output of MANAGE and interpret the results. An expert system is best suited for this type of challenge. Here we detail an expert system called FOREX designed for managing even-aged upland oak forests on steep terrain.

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DOMAIN OF FOREX

The stand tables used to initiate the simulations were those published by Schnur (1937) for even-aged upland oak/hickory forests. Five sites with indices 40, 50, 60, 70, and 80 which are rated worst, bad, average, good, and excellent, respectively, are considered in this expert system. These site indices cover the majority of the range of tree growth characteristics of the development and yield potential available in the northeastern area of the United States. The management plan is to reduce each 2-inch diameter class of trees by 30 to 50 percent to simulate thinning the stand and 100 percent to simulate final harvest. This is a common approach for thinning stands. Thinning could be performed a number of times during the life of the stand before final harvest. Thinning is used as a variable; the user has the choice of performing from one to three thinnings before final harvest. Although we only highlight the results of the oak hickory database with the above mentioned treatments, the user could run MANAGE for the scenario of interest and thus expand the database.

The average slope yarding distance specified is 200 and 400 feet. In reality, any yarding distance may be used on the terrain in which the harvesting is being performed, but the forest manager could easily control the yarding distance to conform to the above mentioned values.

The grading of logs is controlled by a parameter called buck type. A value of 1 for buck type allows logs to be graded based on the length and diameter at each end regardless of where in the tree the log came from. A value of 2 for buck type, although essentially the same as buck type 1, allows only the butt logs to be graded as a grade 1 log. In this demonstration, the buck type was a user-specified variable.

The species mix is held constant throughout the simulations. The species mix included white oak, red maple, red oak, and hickory based on Schnur's (1937) tables and species commonly found in the oak/hickory upland oak range of the northeastern area of the United States. The species remained the same for each site index. Again, the user can manipulate species composition and related analysis for any scenario of choice and add to the database.

The yarders used for harvesting were Bitterroot for stands 7 to 9 inches in dbh, Koller K-300 for stands 9.1 to 16 inches in dbh, and Ecologger I for stands greater than 16 inches in diameter. The one-way mileage from the landing to the mill was assumed to be 25. The delay cost per cubic foot, the move cost per cubic foot, and the PNW discount rate were assumed to be 0.03, 0.03, and 0.03, respectively. Mill prices (in 1,000 board feet) for the logs by grade and by species were:

	Grade			Cordwood
Species	1	2	3	Cord volume
Red Maple	200	125	50	40
White Oaks	450	250	100	40
Red Oak	450	250	100	40
Hickory	210	160	100	40

The road class ranges from 2 through 6, with decreasing speed characteristics as class increases. The trucks that haul the logs are classified based on their capacity. The truck class ranges from 1 through 5, with decreasing capacities as class increases.

The scenarios within the domain of FOREX were limited to outcomes that breakeven or result in profitable ventures. Outcomes that did not breakeven were not included in the database.

The choice of the variables influencing the harvesting of the forest stand has been made by USDA Forest Service experts at the Northeastern Forest Experiment Station based on those that would provide the most applicability in the forest management domain (LeDoux 1986, LeDoux et al. 1994).

RESULTS FROM MANAGE

For each site index, given type, and for different combinations of the variables, MANAGE was executed approximately 1,000 times. Figure 1 shows the various combinations for which the runs were performed. The objective was to execute MANAGE for a specific set of conditions and change the age at which the harvesting activities are done so that breakeven is achieved.

Figure 2 shows a sample MANAGE simulation run. The results from MANAGE show age of the stand when the activity was performed, the number of trees that were present, average dbh, the volume of wood harvested, the sale cost of the wood, the cost of logging, and the PNW.

In this manner, until financial breakeven was achieved in each run, MANAGE was executed for different site indices, thus bringing the total number of runs to approximately 4,500. The data generated from such numerous executions of MANAGE were analyzed, organized and captured in DBASE III[4], a database management system.

DATABASE DESIGN

A database file was created for each site index, in DBASE III. The fields used for each record were: the site index; yarding distance; the road class; the truck class; the percentage of thinning; the activity age; the PNW of the activity; the optimal rotation age; the PNW corresponding to the optimal rotation age; the total PNW; the volume of timber by grade 1, grade 2, grade 3, and cordwood; dbh; total volume of timber for all grades; volume of timber for each grade at the optimal rotation age; number of trees cut at the activity age; and average dbh of the trees harvested at the optimal rotation age.

EXECUTION OF FOREX

The flow chart shown in figure 3 illustrates the execution of FOREX. At the start, the user is presented with two options: to obtain information on the PNW, dbh, and the volume for a specific set of management activity parameters (option 1), or to know what type of management activity to perform to attain the desired minimum PNW, dbh, and/or the volume (option 2).

Option 1

When the user chooses option 1, FOREX presents the user with a choice of site indices to specify. After specifying the appropriate site index, the user is then required to specify the values for the constant parameters in the forest management domain, such as the yarding distance, the buck type, the road class, the truck class, and the percentage and the number of thinnings desired. An important and convenient feature of FOREX is that the user can specify the value of any parameter as "unknown" and FOREX will accept it. If all parameters are known, then there will be a unique solution or result. If one or more parameters are unknown, then FOREX will present as many alternate solutions or results as applicable.

The results can be sent to a printer, a text file, or the computer screen, as desired by the user. The output may consist of hundreds of options or a few options depending upon the values of the parameters. The user may be interested in curtailing the number of alternate solutions by specifying a lower bound on the PNW, dbh, and/or the volume of wood obtained from the management activities. Another important feature of FOREX is that it remembers the values of the constant forest stand parameters used in the previous run when the user begins a fresh consultation. This feature enables the establishment of a link between successive executions of FOREX.

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[4]DBASE III, Registered Trademark of Ashton Tate; 1986.

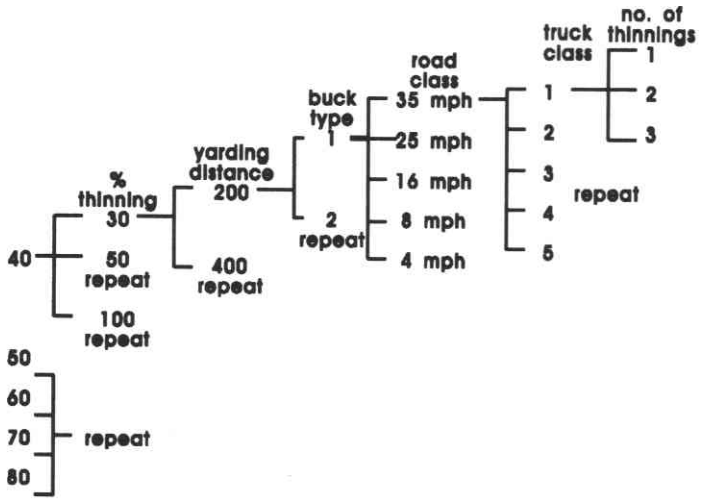

Figure 1. Various combinations of parameters.

MANAGE pc

** COMPLETED ** <↑↓> to scroll summary <ESC> main menu

** data is per acre ** <space bar> acre/tract toggle

Summary of Current Run

Age	Live Trees	AvgDBH (inches)	MerchVolume (ft3)	MillPrice ($)	LoggingCost ($)	PNW ($)
90	226	10.17	3,317.35	2,824.91	1,617.53 v	1,207.38
90	120	12.87	2,906.66	2,686.47	1,332.43 v	1,354.04
90	106	5.73	410.70	138.44	512.40dv	-373.97
100	106	7.32	691.58	233.12	470.09 v	-160.09
110	103	8.82	1,030.64	347.41	560.57 v	-97.28
120	99	10.23	1,398.14	471.28	706.48 v	-72.51
130	98	11.61	1,815.57	606.90	870.60 v	-54.93
140	97	12.92	2,287.71	1,018.37	1,055.28 v	-5.19
150	95	14.11	2,725.18	1,975.58	1,222.04 v	71.63
160	94	15.31	3,249.17	3,029.88	1,422.36 v	103.23
170	89	16.34	3,598.45	4,201.04	1,548.25 v	115.09
180	86	17.27	3,972.84	5,540.42	1,685.14 v	112.99
190	80	18.41	4,313.53	7,014.73	1,802.11 v	103.21
200	76	19.37	4,647.73	8,390.10	1,919.06Dv	86.56

***** end of projections *****

Manage Activities: 1 PNW of Activity(s):$ 1354.04

Optimal Rotation Age: 170 PNW of Optimal Rotation:$ 115.09

Range of measures ages: 90 to 200 years Sum :$ 1469.13

Figure 2. Sample MANAGE run.

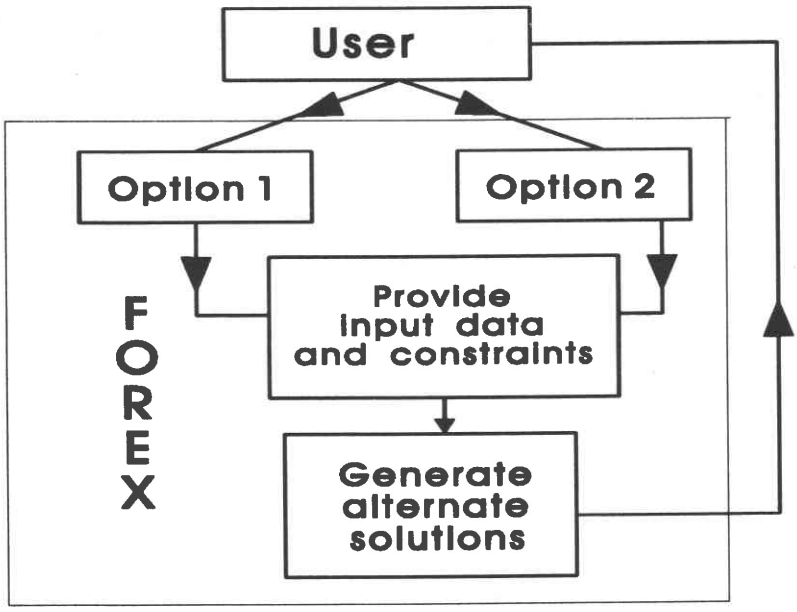

Figure 3. Execution of FOREX.

Option 2

In choosing option 2, the user elects to specify lower bounds on the PNW, dbh, and the volume at the very beginning, even before specifying any values for the forest stand parameters. This option is usually chosen by users who are not aware of the forest stand parameter values but do have a clear understanding of the objectives they want to achieve. They may be interested in obtaining a minimum PNW, and/or a minimum dbh, and/or a minimum volume of wood, and they do not care which management activity is used to attain them.

Thus, after choosing option 2, the user is asked to specify the lower bounds on the PNW, dbh, and/or the volume. The dbh and the volume constraints can be set for the last activity, whereas the PNW constraint can be set as a sum for all activities performed. This is followed by the specification of the forest stand parameters--again it is acceptable for many of these parameters to be "unknown." The second option presents a set of management activities that will meet or exceed the user-specified lower bounds.

If the user is presented with a large number of alternative solutions, the user may be interested in curtailing the number of solutions, as described for the first option. Although the program will cease to execute after providing the solutions for the second option, an important feature of FOREX is that it remembers the lower bound values used for the objectives in the previous execution of the FOREX second option. As for the first option, the results of the second option can be sent to a printer, a text file, or the computer screen. In both options, when the number of alternate solutions is less than five, the results will only print to the screen.

SYSTEM DESIGN FEATURES

As stated previously, the system is able to handle user-specified values of "unknown" to any variable. This situation is a characteristic of an expert system. If any variable is labelled as "unknown," the system reacts by finding the solution space that accommodates all possible values of the variable, if the user is pursuing the first option. On the other hand, if the user is pursuing the second option, wherein constraints are placed on the PNW, wood volume, and tree diameter, the system finds the solution space accommodating only those values of the "unknown" variable that lead to the values of PNW, wood volume, and dbh satifsying the constraints.

If the user would like to execute FOREX using the values of variables specified in the previous run, the system is designed to "remember" the values of the previous run. The system asks if the user wants to use those values. This aspect of system design facilitates sensitivity analysis.

OUTPUT OF FOREX

A typical output from FOREX is shown in figure 4. The user has chosen option 1 with a site index of 40, yarding distance of 200 feet, road class 4, (16-mph road), truck class 2, and buck type 1. The next question presented to the user is the level of thinning desired. The user states the answer as "unknown". The system then determines the number of alternate solutions as 7. This means that there are seven ways (options) to harvest the stand and realize benefits. Option 1 refers to full harvest. The optimal rotation age and the PNW are reported along with wood volume and the number of trees cut. Similar information is provided for option 2, which specifies 30 percent thinning once. Output includes average dbh of the trees, number of trees, the total volume of timber in cubic feet, along with the volumes of each grade (grades 1 through 3) in board feet and for grade 4 in cubic feet, PNW. The output can be sent to the computer screen, a text file, or to the printer. The useful aspect regarding the system is that the user can specify the name of the ASCII file and the system will not only create it, but also successfully append all results of all consultations with FOREX in that file, if the user so desires. Thus, the FOREX system design facilitates iterative use and hence generates a number of alternatives from which the user can select the best.

CONCLUSIONS

FOREX is an expert database integrated system that uses the data from simulation runs. It provides the user with the ability to perform sensitivity analysis and eliminates the need to sort through simulation runs. FOREX is an intelligent computer software that uses the principles of articifial intelligence and interfaces effectively with a database management system to bring a powerful tool into the hands of the forest manager.

LITERATURE CITED

LeDoux, Chris B., MANAGE: a computer program to estimate costs and benefits associated with eastern hardwood management. NE-GTR-112. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1986. 7 p.

LeDoux, Chris B., May, Dennis M., Johnson, Tony, and Widmann, Richard H. Assessing the feasibility and profitability of cable logging in southern upland hardwood forests. Southern Journal of Applied Forestry. 1994 (In press).

Schnur, L.G., Yield, stand, and volume tables for even-aged upland oak forests. Tech. Bull. No. 560, Washington, D.C.: U.S. Department of Agriculture; 1937. 87 p.

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**********************************************************************
Option 1   Site:40      Yarding Distance:200     BuckType:1
               Road Class:4  Truck Class:2       Origin: 1932

                The activity chosen is full harvest.

Optimal Rotation Age (ORA) is 160 years.
                                      PNW at ora is $88
The Average DBH is 14.12 inches.

Total Volume    = 4383 cu.ft
Grade 1 = 4971 board ft.
Grade 2 = 774 board ft.
Grade 3 = 159 board ft.
Grade 4 = 3104 cu.ft.
# of trees = 150

**********************************************************************
press any key to continue!!!
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**********************************************************************
Option 2   Site:40      Yarding Distance:200     BuckType:1
               Road Class:4  Truck Class:2       Origin: 1932

Suggested activity is 30 % thinning 1 time.

Thinning        First      Full Harvest

Age (years)           130        160
# of Trees            62        120
DBH (inches)       12.02      14.50
Volume(cu.ft)         1262       3732
G1 (bd.ft)             486       4859
G2 (bd.ft)               0        175
G3 (bd.ft)             339       1058
G4 (cu.ft)            1046       2313
PNW ($)                  7         78

**********************************************************************
press any key to continue!!!
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Figure 4. Sample output from FOREX.