A DECISION-MAKING MODEL FOR MANAGING OR REGENERATING SOUTHERN UPLAND HARDWOODS

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Abstract—A decision-making model for managing or regenerating southern upland hardwoods is being created for three physiographic provinces including the Cumberland Plateau, Western Highland Rim, and Upper Coastal Plain. The model performs a stand evaluation, from a silvicultural standpoint, and declares a stand as being either manageable or in need of regeneration. Model variables include species class, diameter, height, grade, vigor, crown class, and tree-preference class. Each of the variables is used to generate a stand-index value that must meet a predetermined cutoff value in order for a stand to be considered manageable. Any index value below the cutoff value will return a decision to regenerate the stand.

INTRODUCTION

A large number of species, long rotation age and a shortage of professional hardwood silviculturists combine to increase the difficulty of making hardwood management decisions. Evaluating hardwood stands requires appreciable knowledge and expertise in hardwood management. The initial decision is to determine if an existing stand is manageable or in need of regeneration. In pine management, a resource manager may have one or two species to be concerned with, whereas a hardwood manager must typically deal with multiple species. Hodges and Switzer (1979) noted the great diversity in species composition led to many of the silvicultural problems, which chiefly centered on the maintenance of desired species composition. According to Smith (1988), the cyclic nature of market values and popularity of certain woods made selecting a preferred species a questionable practice.

Long rotation age is another factor that increases the difficulty associated with hardwood management decisions. Rotation ages for sawtimber production generally range from 50 to 70 years, and if no management techniques are employed, rotations can run much longer. Long rotation age affects the decision process in that any stand decision may have to be dealt with for an extended period of time. For experienced hardwood professionals, making decisions on a stand's management potential is not usually difficult, especially when the stand has an extremely low or high management potential. Stands considered borderline in management status are generally the ones that create uncertainty. Furthermore, if the hardwood forester is not experienced, this decision may become difficult for any hardwood stand (Manuel 1992).

There are few hardwood models currently available to resource managers. Some of the models that do exist, such as SILVAH, base decisions on multi-resource attributes that emphasize timber production and wildlife, biodiversity, aesthetic, water, and environmental goals (Marquis and Stout 1992). These variables are certainly important; however, they can be extremely complex.

Loftis and McGee (1993) stated that regeneration prediction models were lacking for many ecosystems where oaks are important and for regeneration techniques other than clearcutting. Belli and others (1999) proposed a hardwood regeneration model that suggested advance regeneration is the key to establishing less tolerant species on southern hardwood sites. Though some regeneration models do exist, there remain regeneration aspects to be modeled. Other models for upland hardwoods involve growth and yield. G-HAT, GROAK, TWIGS, and GROPOP are among the growth and yield models for upland hardwood stands. G-HAT is a computerized growth and yield model designed for thinned hardwood stands in the Blue Ridge Province in the Southern Appalachians (Harrison and others 1986). GROAK is a growth and yield model for upland oaks at the stand level, TWIGS is an individual tree-growth model for yellow poplar, and GROPOP is a stand level growth and yield model for yellow poplar (Perkey and Carvell 1988). The primary difficulty with hardwood growth and yield models is that they are site and species specific, which can limit their use.

Hardwood management and regeneration decisions begin with an evaluation of the present stand conditions. Manuel (1992) completed a management/regenerate decision-making model for bottomland hardwoods in the South. This model is based on establishing an index for stand conditions according to stocking levels of desirable species, tree-preference class, and individual tree characteristics. Under Manuel's system, a stand's index value must meet a cutoff index value, which is based on certain ownership objectives. The current study will draw from this idea and focus on upland hardwood sites in an attempt to complete the modeling of manage/regenerate decisions for southern hardwoods. The objectives of this study are (1) to produce a manage/regenerate decision-making model for southern upland hardwood stands that is based on a stand's management potential from a silvicultural standpoint and (2) to incorporate the model into a computer program that will be available to end users.

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METHODS AND MATERIALS

Study Sites

Three physiographic provinces are being modeled including the Cumberland Plateau, the Western Highland Rim, and the Upper Coastal Plain. The areas of interest within these sites involve high-quality hardwood sites capable of producing quality sawtimber products. Lower quality sites within these provinces may be more suitable for pine or hardwood pulpwood production. In general, the higher quality sites are on the mid- to lower slope topographic positions. It is the mid- to lower slopes that have been sampled for the model.

Field Procedures

A minimum of 12 half-acre (83.3 foot radius) plots have been established in each province. Each plot has been selected to represent a particular set of stand conditions. The variation in stand conditions is designed to express a range of management potential (from low to borderline to a high management potential). The variation in management potential is primarily adjusted by the stocking of desirable species and quality of the trees within the stand.

Each plot is established using a radius of 83.3 feet from plot center. Using a GPS unit, every plot is recorded by its latitude and longitude. Plot boundary lines have been flagged for recognition. Beginning from a north line, individual tree characteristics (species class, diameter, tree class, etc.) are recorded for each tree within the half-acre plot. Species, species class, diameter at breast height (d.b.h.), and tree class are recorded for all trees larger than 5 inches in d.b.h. Merchantable height, grade, vigor, and crown class are only recorded for trees greater than or equal to 12 inches in d.b.h.

Each plot is being evaluated by an expert panel consisting of nine members. The panel consists of corporate, government (State and Federal), and university hardwood professionals that have expertise in upland hardwood management. The panel will evaluate each stand and determine if it is either manageable or in need of regeneration for each management objective. The goal is to have the expert decisions coincide with the decisions of the model. The usefulness of the model will be gauged by the level of agreement between the hardwood professionals' decisions and the model's decisions.

Model Description

The model assigns points to individual tree characteristics and accumulates the points for each characteristic into a tree value. The individual tree values are accumulated into plot values, which are adjusted to overall stand values. The model includes a series of objectives that can be used to apply constraints to a given stand. The total value for a given stand is compared to the cutoff value for a given objective, and the model makes a decision to either manage or regenerate the stand in question. If the overall stand value exceeds the cutoff index value, the model returns a decision to manage the stand. Alternately, if the stand value is below the cutoff value, the model decision is to regenerate the stand.

The Function of Individual Tree Characteristics

Individual tree values are determined through point values assigned to individual tree characteristics. The tree characteristics are comprised of additive and multiplicative variables. The additive variables include species class, merchantable height, butt log grade, tree vigor, and crown class. The multiplicative variable for the model is tree class. The function of d.b.h. in the model is to provide a tree with its initial value (or maximum value). The sum of the additive tree characteristics equals 12 points, and the percent of the 12 possible points a tree receives is used to adjust the initial value of a given d.b.h. This adjusted tree value is then multiplied by a percent value for a particular tree class (such as a tree in the reserve tree class receives 75 percent of a given amount of possible points) to provide the tree with its final value (table 1).

Additive Variables

The additive variables used in the upland model include species class, crown class, butt log grade, merchantable height, and vigor. Each of these tree variables is assigned a rank and a point value for each rank. Species class and crown class may receive more points than merchantable height, vigor, and butt log grade (table 1). The total amount of points allowed for all individual tree characteristic variables combined is 12. The percentage of total points captured is calculated for the additive variables in each tree (i.e. 10 out of the 12 possible points equal 83.3 percent). The percent captured from the additive variables is then used to adjust a given tree value.

Table 1—Variables used in the upland decision-making model

Additive variables	Rating	Point value
Species class	Desirable	3
	Acceptable	0
Merchantable height	2.5 logs or higher	2
	1.5 to 2.0 logs	1.5
	1.0 log	1
Butt log grade	Grade 1	2
	Grade 2	1.5
	Grade 3	1
Vigor	High	2
	Medium	1.5
	Low	0.5
Crown class	Dominant/codominant	3
	Intermediate	1.5
	Suppressed	0.5
Multiplicative variable	**Rating**	**Percent**
Tree class	Preferred	100
	Reserve	75
	Cutting stock	-25
	Cull	-25

There are three possible ratings that can be assigned to species class, including "desirable", "acceptable", and "unacceptable". The desirability for particular species has been established through a review of the literature and input from hardwood resource managers in the areas modeled. Furthermore, desirability levels for different species are designed to meet the ownership objectives, which relate to management goals, in the model. Desirable species are those that are considered suitable for the management objectives. For a species to be considered "desirable", the species must be sufficient for a crop tree. In other words, a desirable species is appropriate for the management objectives and should be included in future stand management. Desirable species receive the highest points of the three species ratings (3.0 points) in the model. Acceptable species are those that are considered acceptable for the management of the current stand but would not be a desirable crop tree in future stands. Acceptable species do not add points to the additive value of a tree (0.0 points). Essentially, acceptable species have some value in the current market, but not enough to be involved in future stands. Unacceptable species would not be suitable crop trees nor would they be acceptable in the current stand. Unacceptable species have little to no market value and should not be a part of timber production management. Unacceptable species are simply classified as cutting stock trees and apply a negative value to the stand.

Crown class is a major individual tree characteristic in the model. The crown-class variable may receive up to 3 points in the model. Crown class is broken down into four categories: dominant, codominant, intermediate, and suppressed. Dominant and codominant crowns receive 3 points, intermediate crowns receive 1.5 points, and suppressed crowns receive 0.5 points.

The role of butt log grade in the model is to incorporate a variable that represents stem quality. There are three butt log grades that are assigned a value in the model. Grade one logs receive 2.0 points, grade two logs receive 1.5 points, and grade three logs receive 1.0 point. Trees that fall into the grade 4 category are assigned to the "cull" tree class; however, sound grade 4 trees are assigned to the "cutting- stock" class. The grades are based on the USDA Forest Service grading criteria (USDA Forest Service 1981). Smaller sawlog trees, trees from 12-to 14-inch d.b.h. classes, do not provide a proper scaling diameter by the grading criteria. Therefore, the smaller sawlog trees have been graded using a subjective analysis of the trees future potential.

Merchantable height is recorded in logs and half logs for trees equal to or larger than 16 inches in diameter. The 12- and 14-inch diameter trees generally receive 1 log. The minimum acceptable merchantable height in the model is 1 log (16 foot). Trees with a merchantable height of 2.5 or more logs receive 2.0 points in the model. Trees with a merchantable height from 1.5 to 2.0 logs are assigned 1.5 points, and trees with 1 log are assigned 1.0 point.

The vigor variable is evaluated on a subjective basis. Vigor estimations are based on a growing stock trees' crown and trunk. The tree crowns are evaluated for fullness (relative to species) and presence of die-back (dying limbs). The trunks are evaluated by an estimation of growth rate and condition (damage or defect). The vigor class is incorporated to provide a value for overall tree health. There are three classes of vigor: high, medium, and low. High-vigor trees receive 2.0 points, medium-vigor trees receive 1.5 points, and low-vigor trees receive 0.5 points.

The Multiplicative Variable

The multiplicative variable, tree class, is one of the most important variables in the model. Each tree value is adjusted by its tree class to provide a final tree value. There are four categories of tree class including preferred, reserve, cutting stock, and cull (Putnam and others 1960). Preferred growing-stock trees are "crop trees" that will be managed throughout the entirety of the rotation. Therefore, preferred growing-stock trees receive 100 percent of their potential value. For example, a 20-inch preferred growing-stock tree (2.44 possible points) that captured 10 out of 12 points (83.3 percent) for individual tree characteristics contributes (2.44 * 0.833 * 1.0 = 2.03) 2.03 points to the plot value. Reserve stock trees are trees that are in good condition but do not qualify as preferred stock or may not be capable of remaining in the stand throughout the rotation (due to loss of vigor). Reserve growing-stock trees capture 75 percent of their potential value. For example, a 20-inch reserve growing-stock tree (2.44 possible points) that captured 10 out of 12 points (83.3 percent) for individual tree characteristics contributes (2.44 * 0.833 * 0.75 = 1.52) 1.52 points to the plot value. Cutting-stock trees are either of an unacceptable species or in risk of mortality within the next 10 years of management. Cutting-stock and cull trees apply a slightly negative value (-25 percent). For example, a 20-inch cutting-stock or cull tree (2.44 possible points) contributes (2.44 * (-0.25) = -0.61) -0.61 points to the plot value.

Role of Management Objectives

The upland hardwood decision-making model employs a variety of management objectives, which assist in making a resource manager's decisions meet the desired goals. The primary variables that can be adjusted in the model are (1) the acceptability of yellow poplar and sugar maple and (2) whether a 20-inch diameter limit is to be applied. Each management objective affects the stand value and the cutoff value for a given stand. The objective affects stand value through causing adjustments in the values of trees over the maximum allowable diameter. Also, each objective contains a predetermined cutoff value to be used in stand analysis.

Stand Index Value vs. Cutoff Value

After a stand value is generated for a given objective, it is compared to the predetermined cutoff value for the objective. Any value equal to or above the cutoff value returns a decision to manage the stand and any value below the cutoff value returns a decision to regenerate the stand. Stand values that are near the cutoff value are borderline stands. Therefore, a model decision to manage or regenerate a borderline stand means the stand's management potential is leaning towards the decision. In borderline stands, there may be many factors that potentially influence the stand's management potential.

Conversion of Manuel's Bottomland Hardwood Decision-Making Model

Manuel's bottomland hardwood decision-making computer program was created using a Microsoft Disk Operating System (MS-DOS) format in the FORTRAN language. During the time the program was created, MS-DOS computer programs were common and acceptable. However, today with the availability of higher level computer languages such as Visual Basic, Visual C++, Visual C#, and Java, the need to update desirable MS-DOS programs into a Windows environment is important. Manuel's program employs a series of screens filled primarily with list boxes used to retrieve data from the user. Initial stand information including: stand name, plot size, and the mode in which to run the program (2 types: "Demo" and "Cruise"), are retrieved through a series of input screens. The two run modes allow the user to enter stand data in different forms. Demo mode requires the most information about a given stand and produces a more "finely tuned" stand index. Cruise mode requires less information that is usually included in standard inventory cruises. The primary difference between the two modes is that in Demo mode the user must input the tree grade, vigor, crown class, and height, whereas in Cruise mode the user only enters species, species class, diameter, and tree preference class. The end result is that Demo mode provides a more exact result than Cruise mode. Manuel's program retrieves stand data through a spreadsheet screen that contains list boxes for most of the variables.

The new Windows-based program adds a significant amount of functionality to the program. The new program uses spreadsheets containing editable cells and list boxes within dialog boxes to retrieve data from users. The primary element that increases the functionality of the program is the ability to easily edit input variables. This allows the user to quickly see the effects of changing variables, such as the effect on stand value from changing the desirability of certain species.

RESULTS AND DISCUSSION

Because the evaluations of the expert panel are currently being conducted, only preliminary results can be presented at this time. The Cumberland Plateau is providing the highest potential cutoff values in the initial stand analyses. Preliminary stand analyses for the Cumberland Plateau and the Western Highland Rim are presented in figs. 1 and

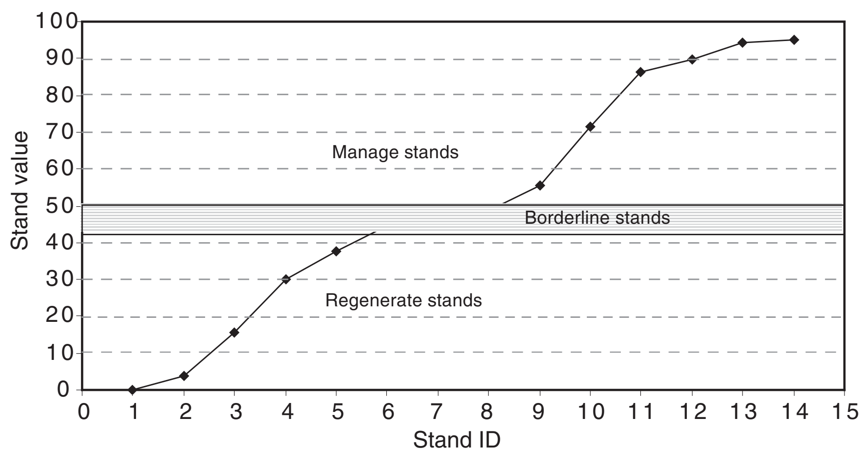

Figure 1— Preliminary stand analysis for the Cumberland Plateau.

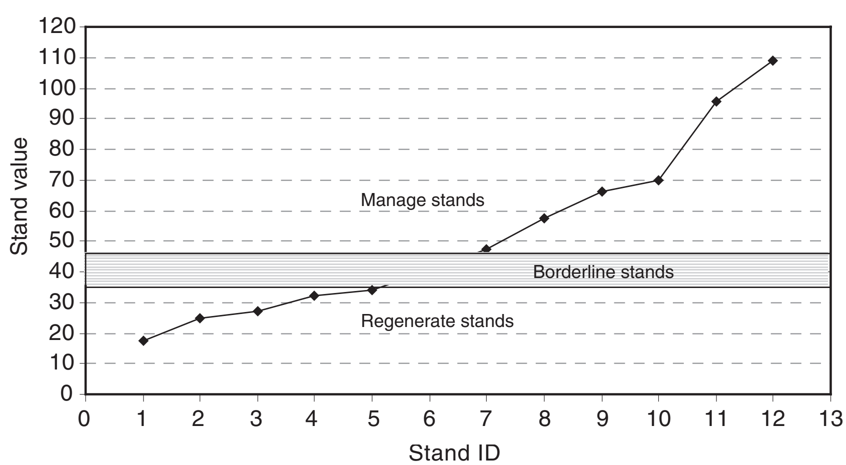

Figure 2—Preliminary stand analysis for the Western Highland Rim.

2. Due to insufficient data at this point, initial stand values for the Upper Coastal Plain are not shown. Initial Stand values for the Cumberland Plateau Province range from 0 to 95. The borderline stands appear to have values that range from 43 to 50. Stands with values below 30 appear to be strong regenerate stands. Stands with values over 70 appear to be highly manageable (as seen in fig. 1). Initial stand values for the Western Highland Rim range from 17 to 109. The borderline stands appear to have values that range from 37 to 47. Stands with values below 30 appear to be strong regenerate stands; stands with values over 60 appear to be highly manageable (fig. 2).

SUMMARY

The product of this study is a decision-making model, which is incorporated in a computer application, for managing or regenerating southern upland hardwoods. The model is an extension of Manuel's (1992) bottomland hardwood decision-making model. The primary variables used in the model include stocking of desirable species, tree preference class, and individual tree characteristics. These variables are used to generate tree values, which are accumulated into plot values and converted to overall stand values. There are four objectives used to represent different management goals in the model. A stand value is compared to the cutoff value for a given objective. Any value greater than or equal to the cutoff value returns a decision to manage a stand. Alternatively, any values less than the cutoff value return a decision to regenerate a stand.

Individually, the expert panel determines each stand to be either manageable or in need of regeneration for a given objective. The decisions of the model are compared to the decisions of the expert panel to gauge the usefulness of the model. At this time, the review by the panel members is being conducted. This model is designed to assist in determining the management potential of upland hardwood stands. Determining whether a stand is manageable or in need of regeneration must be accomplished before any silvicultural prescription is applied. Furthermore, the generation of an upland model, along with the conversion of the bottomland model to Windows, is an attempt to set the stage for completing the modeling of manage/regenerate decisions for southern hardwood stands.

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