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Site Index Prediction for Willow and Cherrybark Oaks in East Texas Bottomland Forests

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Abstract

Estimating site quality for a specific tree species is an important tool in forest management. While intensively managed pine species are often the focus of site quality studies using site index, hardwood species found in bottomland hardwood sites are often lacking in quality growth prediction equations. Two valuable hardwood species, willow oak (*Quercus phellos*) and cherrybark oak (*Q. pagoda*), are of interest for forest managers of east Texas bottomland sites. The objective of this study was to develop site index prediction equations and curves for these two species. Using height and age data from 267 cherrybark oaks and 460 willow oaks collected from sites across east Texas, remarkably similar equations were developed, with coefficient of determination (R^2) of 0.63 for cherrybark oak and 0.52 for willow oak.

Keywords: Site index; Hardwoods; Cherrybark oak; Willow oak

Introduction

Of the 72.8 million ha of commercial forest land in the southern United States, approximately 4.8 million ha may be found in east Texas, approximately 728,000 ha of that have been classified as bottomland types [1]. Bottomland types refer to low lying flood plains along river systems characterized by typical relief features such as bars, fronts, sloughs, ridges, flats and swamps with slight changes in elevation [2]. While potentially very productive for a variety of hardwood species, species composition is greatly influenced by levels of drainage, soil texture, soil moisture, soil structure and soil pH, with elevational changes of 1 m leading to dramatic changes in productivity [3]. A generalized classification [2] of typical composition was associated with different relief features of minor and major bottoms. Oaks (*Quercus* spp.) are the dominant genera found in bottomlands, providing both excellent timber products as well as valuable habitat needs for a variety of wildlife species.

Two species of high value are cherrybark oak (*Q. pagoda*) and Willow oak (Q. *phellos*). Cherrybark oak at maturity can reach heights of 30-40 m and 90-152 cm in diameter, with a straight bole and often is a dominant species in the canopy [4]. Cherrybark occurs mainly on loamy sites on first bottom ridges and on well drained terraces and colluvial sites of both major and minor streams which are subjected to periodic but irregular flooding. Willow oak can reach 36 m in height and up to 101 cm in diameter, but its growth rate is moderate compared to its associates on higher productive sites; they develop best on clay loam ridges [5]. These oaks grow on a variety of alluvial soils occurring on ridges and high flats on first bottoms of major streams; in minor stream bottoms, they are found on ridges, flats, and sloughs.

While there are many methods available to estimate site productivity for tree species, one of the most common and simple to use is site index, which is based on measured and/or estimated growth (height or diameter) of trees against age. Since bottomland hardwood forests are inherently diverse in tree species, work in this area has been less common than the development of site index for less diverse forests or pine plantations.

Objectives

To meet an increasing but sustainable demand for products from thee oak species, often intensive management is required, and site quality information is needed to facilitate planning and management. The overall goal of this project was to quantify site quality estimates for cherrybark and willow oaks for east Texas bottomland hardwood forests. The specific objectives were:

- To develop estimated height equations using age;
- To convert height growth equations into anamorphic site index prediction equations to estimate site productivity;
- To develop site index curves for these two-species using the site index prediction equations.

Methods

Study area

Sites in twelve counties (Angelina, Cherokee, Hardin, Houston, Jasper, Nacogdoches, Newton, Orange, Sabine, San Augustine, Shelby, and Trinity) in east Texas were utilized for this study (Figure 1). These sites ranged from bottomlands with periodic standing water to lower upland slopes along smaller streams and creeks, commonly called minor bottoms [3].

Field data collection

Sampling points along transects were established systematically at numerous sites, with 100 m between transects and 60 m between sampling points. At each point, a BAF-10 prism was used to identify trees to be sampled and data collected on diameter, height, bark thickness, crown width, form, and log grade [6].

Increment cores were taken from each sample tree using an Addo

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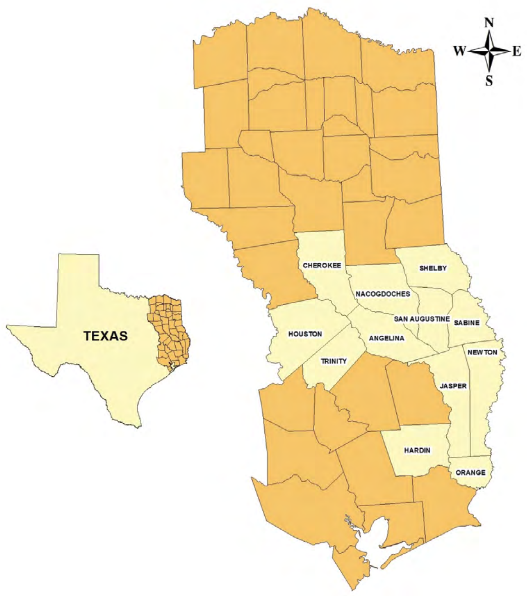

Figure 1: Map of counties in east Texas where plots were located for this study.

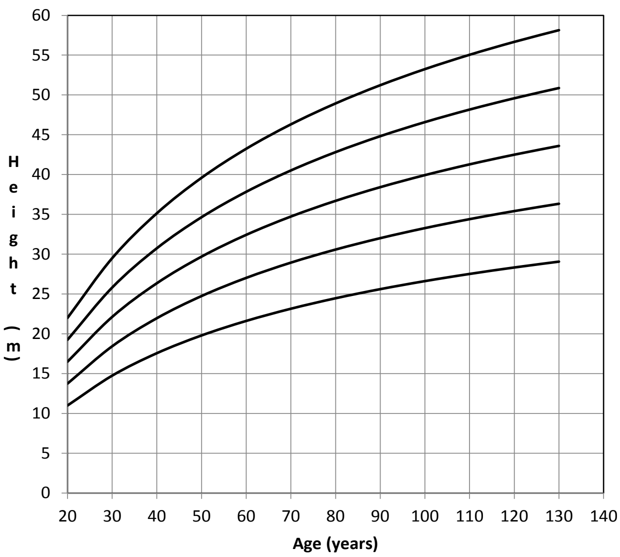

Figure 2: Regression-derived Site index curves at base age 50 for Cherry bark oak in bottomland hardwood stands of east Texas.

Dendrochronometer and each core sample recorded by species, sampling point and transect line. Age was determined from growth ring counts backwards from the most recent growth to the pith in each core. Additional notes on canopy position and vigor was also made for each sample tree. Sampled trees met the following characteristics:

• At least 20 years old in a dominant or codominant crown position.

• Occurring in even-aged, well stocked (60-80% stocking [7]) with little identifiable disturbances.

• No observed crown deformities from ice or lightning.

• Free from disease, sweep, forking, crook or prolong suppression as determined from field assessment, grading or age coring.

Regression equations to predict total height from age were then developed using SAS on data from 267 cherrybark oak and 460 willow oaks. Various regression equations in both untransformed and logarithmic transformation forms were performed and the results analyzed. Using the best fit regression formula from the data, site index curves and site index estimation equations were developed.

Results

The 727 total trees used in this study ranged from 20-120 years in age, and were placed into 10-year age classes, with a resulting uneven distribution with high numbers in the 30-39 and 80-89 ages classes, most likely due to past management activities or natural mortality (Table 1). The equation that best fit the actual data for both species was:

$$\text{Ln }(H)=b_0-b_1(A^{-1/2})$$

where, ln=natural logarithm; H=Total height; b_0=y-intercept coefficient; b_1=slope coefficient; A=age.

Height-age regression equations for both species (Table 2) were developed with the coefficient of determination of 0.63 (cherrybark oak) and 0.52 (willow oak). The y-intercept coefficient for both species may have been caused by the range of tree ages used in the sample (20-120 years) from one-time height–age data, making the y- intercept of little value. If we had used the stem analysis method, regression would have been naturally forced through or near the origin.

Cherrybark Oak: $\ln(H)=5.56-7.15(A^{-1/2})$

Willow Oak: $\ln(H)=5.38-6.83(A^{-1/2})$

Site index curves for both species were developed from the above height-age regression equations, following [8] for guide curve development with steps of transformation, definition and arrangement (Table 2). The resulting site index curves (Figures 2 and 3) ranged from 24 m to 36.3 m at base age 50. Using the site index prediction equations, various site indices for both species were calculated for values between the above 24-36.3 m height range (Tables 3 and 4) to confirm the predictability value of the site indices.

Discussion

Anamorphic site index curves developed from regression are widely used [9], and are much more accurate than older, manually drawn proportional lines. However, they do exhibit inconsistencies compared to polymorphic site index curves. The differences are often based on the premise that anamorphic curves assume constant growth across different site qualities; even though trees grow at different rates over time under different site qualities. When polymorphic curves are derived from stem analysis under narrow site qualities and geographic ranges, this variation in growth patterns may be easily observed [10,11]. Ideally, polymorphic site index curves would provide a better estimation of site quality for these species, but such curves do not exist. As a result, these curves are a good first step in improving management of these species, and are of value until polymorphic curves are developed.

The similarity of site index curves for these two species may have been influenced by the unequal sample sizes (267 and 460) utilized, and the high number of samples in two age classes (30-39 and 80-89 years). Evaluating the same data for their height range within same age classes also showed uneven results (Table 5) with the larger ranges noted in the age classes with the highest number of samples. This may have resulted

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Species	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-120	Total
Cherrybark Oak	15	21	39	53	67	31	16	11	11	3	267
Willow Oak	19	76	110	100	86	26	24	14	3	2	460

Table 1: The number of sampled Cherrybark and Willow Oaks by age class used to determine site index curves from sites in east Texas.

	Cherrybark Oak	Willow Oak
Height-Age Regression[1]	$\ln(H)=5.56-7.15(A^{-1/2})$	$\ln(H)=5.38-6.83(A^{-1/2})$
Site Index Guide Curves	$H=S \times e^{-7.15(A-1/2-0.14)}$	$H=S \times e^{-6.83(A-1/2-0.14)}$
Site Index Calculation	$S=H/e^{-7.15(A-1/2-0.14)}$	$S=H/e^{-683(A-1/2-0.14)}$
[1]R^2 for Cherrybark=0.63; Willow oak=0.52		
H=Height (m)		
A=Age (years)		
S=Site Index (m)		
in=natural logarithm		

Table 2: Equations used in developing site index curves for Cherrybark and Willow Oaks in east Texas.

	Total Age (years)									
Total Height (m)	20	30	40	50	60	70	80	90	100	110	120
			Site Index (m)								
40	73										
50	91										
60	109	81									
70		94	80								
80		108	91	80	74						
90			102	90	83	78					
100			114	110	93	86	82	78			
110				110	102	95	90	86			
120					111	104	98	94	90	87	85
130					120	112	106	102	98	94	92

Table 3: Site Index prediction equations results for Cherrybark Oak for east Texas bottomland hardwood sites.

	Total Age (years)										
Total Height (m)	20	30	40	50	60	70	80	90	100	110	120
			Site Index (m)								
40	71										
50	88										
60	106	80									
70		94	79								
80		106	91	80	74						
90			102	90	84	78					
100			113	110	93	87	82	79			
110				110	102	96	91	87	84	81	79
120					111	104	99	95	91	88	86
130					120	113	107	103	99	96	93

Table 4: Site Index prediction equations results for Willow Oak for east Texas bottomland hardwood sites.

	Age Class (years)										
	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-120	Total
					Cherrybark Oak						
N (trees)	15	21	39	53	67	31	16	11	11	3	267
Height Range											
Highest	58	78	104	111	119	114	120	126	129	135	
Lowest	20	52	45	60	60	70	88	85	98	99	
Range	38	26	59	51	59	44	32	51	31	36	
					Willow Oak						
N (trees)	19	76	110	100	86	26	24	14	3	2	460
Height Range											
Highest	87	92	108	110	119	121	121	123	130	125	
Lowest	30	37	45	50	70	84	89	100	100	120	
Range	57	55	63	60	49	37	32	23	30	25	

Table 5: Tree data by age class used in the development of the site index curves for Cherrybark and Willow Oaks in East Texas.

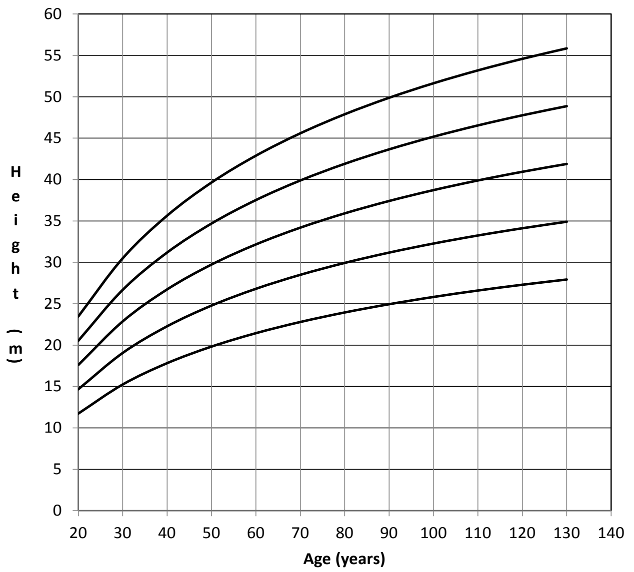

Figure 3: Regression-derived Site index curves at base age 50 for willow oak in bottomland hardwood stands of east Texas.

in the low coefficient of determinations for both species.

When comparing our results to those reported in central Mississippi [12], they are similar up to age 60, where our results were slightly higher (0.3 m) and sustained since our data were from trees much older than their data set (70 years). Significant differences after age 50 were found when comparing our results to another study [13], with our results lower up to age 50 (2.4 m lower at age 40) but higher after age 50. Our results and those of [12] were from sites within relatively narrow range and along mostly minor bottoms, while [13] were from sites across the bottomland hardwood region and included many major river bottoms.

The only comparative willow oak site index curves [13] showed higher early height growth before 50 years and lower growth afterwards when compared to our results. Much like the results of [13] for cherrybark oak, the results from [13] were also from a wide distribution of sites across the south and also included many major river bottoms.

Conclusions

The results of our study show the value of anamorphic, regression-derived site index curves for these two-important species. However, when compared to studies that used a wider geographic range of sites and utilized major river bottoms, the differences in estimated site quality (and therefore height growth) is notable, and reflects the value of subregional, site specific studies to obtain the best site index projections for management.

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