HARDWOOD GROWTH AND YIELD ON VARIOUS SITES IN THE SOUTHEASTERN UNITED STATES

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ABSTRACT

Occupying over 36 million hectares including some of the best sites in the South, natural hardwood stands comprise one-half of the growing stock on 40 percent of the region's commercial forest land. These stands are typically of mixed species, occurring on a wide variety of sites, and are utilized for a multitude of end products. Yields are related to variables such as site, basal area, age, stand quality, merchantability limits, harvesting techniques and others. Yet broad generalizations are frequently used to describe growth and yield of natural hardwood stands, which are inadequate for management purposes.

The North Carolina State Hardwood Research Cooperative initiated this study in 1969 to obtain more accurate estimates of hardwood growth and yield. Yields from more than 600 one-fifth-acre plots were examined and stratified by site type and age class, and the results published as Technical Report 55 of the N. C. State School of Forest Resources.

This paper refines and updates the original growth and yield estimates from the 600 plots, using the most recently available equations for volume and biomass yields of various aboveground tree components. The importance of several stand parameters which influence yield (such as site, age, basal area and height) is discussed.

KEY WORDS: Growth and Yield, Biomass, Natural Hardwoods

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Naturally occurring hardwoods comprise half the growing stock of the commercial forests in the southeastern United States. Excluding the 20 percent of forest land supporting mixed pine-hardwoods suitable for conversion to pine, there remains one-third of the commercial forest (about 70 million acres) in hardwoods on what we would refer to as permanent "hardwood sites." Occupying a broad spectrum of conditions from Coastal Plain swamps to mountain slopes and ridges, these stands contain a diversity of species and produce a multitude of end products. There is no question that man's activities have greatly influenced the location, extent, species composition and productivity of these mixed hardwood stands, whether through deliberate and repeated high-grade logging, exclusion of fire, or introduction of pests such as the chestnut blight. Differences in stand origin, species composition, productivity rates and environmental conditions all serve to complicate management recommendations. Yet interest in management of natural hardwoods is on the rise. Improved utilization by more efficient merchandising is helping to make these stands a valuable resource. Additionally, projection of a pine fiber "imbalance" is contributing to an anticipated increase in hardwood value for fiber. The current volatile economic situation, especially in the petroleum industry, is rekindling interest in wood as a primary energy source. Even the rising value of land is an added incentive for optimum natural stand management, as it must generate an adequate "return on investment."

Land managers have been constrained by inadequate tools with which to ply their trade in natural hardwood stands. Needed has been an appropriate site classification scheme within which management decisions may be made and applied with some confidence and efficiency. Managers also need a reasonable concept of "normal" yields for various merchandising levels, so that inventories can be compiled and attention devoted to those areas and products of most potential. Finally needed is some idea of the relationships of yield to various factors over which some control might be expressed (Schlaegel, 1977).

To gain information on these subjects, the N. C. State Hardwood Research Cooperative initiated a Growth and Yield Study in 1969. One of the first phases of that study involved delineation of forest site types by geographic location, water drainage patterns, soil structure and species composition. Sites were defined broadly so resulting units could be identified on an operable scale. Individual site types may, as a result, contain either small or ill-defined areas of other types which are not separately identified. The nine resulting hardwood forest site types listed by geographic province are (see the appendix to this paper for site type descriptions):

Coastal Plain	Piedmont and Mountains
Muck Swamp	Bottomland
Peat Swamp	Coves, Gulfs and Lower Slopes
Wet Flat	Upland Slopes and Ridges
Red River Bottom	
Black River Bottom	
Branch Bottom	

A second objective of the Growth and Yield study was to estimate the growth of fully stocked natural stands aged 20 to 60 years on these nine forest site types. Only stands which showed no evidence of recent stocking control or partial harvests were sampled. Results from 640 one-fifth-acre plots were compiled in Technical Report 55, Yields of Mixed Hardwood Stands Occurring Naturally on a Variety of Sites in the Southern United States, published in 1975 and now out of print (Smith, 1975).

As seen in Table 1, growth was rather low, averaging only three-fourths cord per acre per year.

Table 1. Growth of naturally occurring, even-aged hardwoods, by forest site type

Site Type	Growth/Acre/Year (Cu.Ft.)	(Cords)1/
Muck Swamp	76	.9
Peat Swamp	50	.6
Wet Flat	68	.8
Red River Bottom	78	1.0
Black River Bottom	87	1.1
Branch Bottom	68	.8
Bottomland	69	.9
Coves, Gulfs & Lower Slopes	62	.8
Upland Slopes & Ridges	41	.5

1/ Assumes 80 cubic feet of solid wood per cord

This relatively poor performance was attributed primarily to overstocking, as the number of nonmerchantable stems always equalled or exceeded the number of merchantable stems, even at age 60.

Recently an updated analysis of yields of natural hardwood stands has been completed (Gardner, 1980). It incorporates the newest merchantable volume equations for commercial hardwood species, courtesy of Joe McClure, USFS, Asheville, as well as newly available biomass information provided by Alexander Clark and Doug Phillips, USFS, Athens, Georgia.

With improved yield equations, particularly as they affect "residual" aboveground stand components, the objectives of this latest study are to (1) emphasize aboveground biomass as well as multiple product utilization; (2) refine yield estimates and the expected variation within each site type in order to increase the report's utility as an inventory tool, (3) determine the relationship of basal area, an easily measured stand stocking indicator, to stand yields, and (4) improve forest site type descriptions by incorporating appropriate stand table information.

For each forest site type, five pages of tables have been developed. The first includes stand information on heights of merchantable trees, basal areas of various stand components and numbers of stems per acre, as well as the percent of merchantable basal area typically comprised by the several major species. The subsequent four tables express yields in terms of aboveground biomass in submerchantable stems, aboveground biomass in merchantable stems, cubic feet of pulpwood with residual aboveground biomass in merchantable stems, and board feet (International ¼" Rule) of sawtimber with the residual pulpwood component as well as residual aboveground biomass in merchantable trees. Each yield table includes a range of basal areas for each age class. Although space prohibits inclusion of these tables here in detail, some averages, highlights and conclusions follow.

The nine forest site types did differ in typical merchantable and submerchantable basal area (Table 2). These differences in basal area also account for much of the difference in pulpwood (or biomass) yields among site types at a given age. Although those basal areas shown are representative of the growth and yield plots, they are not necessarily representative of the entire forest site type, as efforts were made to sample only "well stocked" stands. In fact, those types consistently reflecting the highest basal area for a given age class were generally the same types most difficult to age accurately--Muck Swamps and Black River Bottoms.

Table 2. Average merchantable and submerchantable basal areas by site types and age classes

Merchantable plus Submerchantable Basal Area in Square Feet per Acre

Site Type	Stand Age				
	20	30	40	50	60
Muck Swamp	102 + 67	119 + 41	142 + 29	172 + 21	208 + 16
Peat Swamp	4 + 100	72 + 73	118 + 51	142 + 33	142 + 20
Wet Flat	68 + 39	93 + 24	122 + 17	156 + 13	193 + 10
Red River Bottom	83 + 34	96 + 23	114 + 18	135 + 15	161 + 13
Black River Bottom	55 + 51	105 + 34	144 + 21	171 + 13	187 + 8
Branch Bottom	82 + 33	105 + 24	123 + 18	139 + 16	150 + 18
Bottomland	72 + 33	97 + 21	118 + 13	133 + 11	144 + 12
Coves, Gulfs and Lower Slopes	83 + 32	100 + 21	112 + 13	120 + 10	122 + 10
Upland Slopes and Ridges	62 + 33	66 + 27	75 + 21	88 + 15	105 + 8

Pulpwood yields and residual aboveground biomass of merchantable stems at age fifty for typical values of merchantable basal area are shown in Table 3. Those sites supporting the highest basal areas (170 square feet) are indeed showing the highest merchantable volumes. For sites of similar basal area, stand height accounts for much of the difference in yields. The amount of aboveground residual, expressed as a proportion of merchantable pulpwood, generally is least on the "best" sites (for example, red river bottoms) and increases as site quality declines. Dry-to-green weight ratios vary slightly according to species composition, most noticeably declining on coves, gulfs and lower slopes where the yellow-poplar (*Liriodendron tulipifera* L.) component is large.

Table 3. Pulpwood and residual biomass yields per acre in merchantable stems of 50-year-old stands by representative basal areas and site types

	Merchantable Basal Area (Sq.Ft.)	Pulpwood Inside Bark (Cu.Ft.)	Residual Tops, Limbs and Bark		
			Volume (Cu.Ft.)	Green & Dry Weight (Tons)	
Muck Swamp	170	3778	2744	66.8	36.1
Peat Swamp	140	3094	2122	54.6	28.9
Wet Flat	150	3634	2415	64.3	35.1
Red River Bottom	130	3246	1930	55.0	30.0
Black River Bottom	170	3810	2352	62.7	34.4
Branch Bottom	130	2861	2072	53.9	29.0
Bottomland	130	3223	2011	55.4	29.7
Coves, Gulfs and Lower Slopes	130	3600	2348	70.0	35.0
Upland Slopes and Ridges	90	2040	1537	47.9	25.8

When these same sites at age fifty are compared, supporting identical basal areas (130 square feet per acre), the most productive sites are red river bottoms in the Coastal Plain and coves, gulfs and lower slopes in the upper Piedmont and mountains (Table 4). This supports our common association of a height-to-age ratio with productivity, as those stands, at 70 and 76 feet respectively, are in fact the tallest.

Additional trends which are supported by more detailed tables include the substantial contribution of residuals to high basal area plots at young ages, a stabilization or occasionally an increase in the number of submerchantable stems in the oldest classes, and a shift toward more tolerant species at the expense of intolerants in the older plots.

Table 4. Pulpwood and residual biomass yields per acre in merchantable stems of 50-year-old stands with 130 square feet of merchantable basal area, by site type

	Pulpwood Inside Bark	Residual Tops, Limbs and Bark		
			Green and Dry Weight	
	(Cu.Ft.)	(Cu.Ft.)	(Tons)	
Muck Swamp	2870	2088	51.7	28.0
Peat Swamp	2874	1979	50.7	27.0
Wet Flat	3181	2109	57.3	31.4
Red River Bottom	3246	1930	55.0	30.0
Black River Bottom	3056	1847	51.4	28.3
Branch Bottom	2861	2072	53.9	29.0
Bottomland	3223	2011	55.4	29.7
Coves, Gulfs and Lower Slopes	3600	2348	70.0	35.0
Upland Slopes and Ridges	3169	2298	70.7	37.1

It is worth reemphasizing at this point that the objective of this latest yield report is not so much the comparison of averages for site types as it is to refine yield predictions for individual stands. To do the latter requires accurate description of a candidate stand and an ability to match it to the appropriate table for site type, age class, utilization and basal area.

Present efforts continue to involve refinement of the current annual growth increments in order to facilitate management decision-making within and among the site types. It is recognized that a majority of the permanent hardwood forest site types are not now, and likely never will be, suited for plantation management. However, a spectrum of options with respect to species and stocking control, site fertility, harvesting and regeneration, ranging from extensive to intensive, are available to the silviculturist whenever yield response can be shown to justify the investment.

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APPENDIX

Coastal Plain

Muck Swamps

These very poorly drained Coastal Plain areas usually retain standing water. Broad expanses exist between tidewater and upstream runs and along black-water rivers and branch bottoms, and they also are found in miniature in sloughs and old oxbows of red-water rivers and branch bottoms. Muck swamps are characterized by heavy accumulation of organic matter (amorphous, lacking structure). Soils range from silt loam through clay. Swamp black-gum predominates, but water tupelo and bald cypress are more common in deeply flooded areas.

Peat Swamp

Peat swamps or headwater swamps occupy broad interstream Coastal Plain areas from which black-water rivers and branch bottoms originate. These swamps are poorly drained with heavy accumulations of raw organic matter. Soils resemble those of muck swamps but in general are heavier. Examples include: The Dismal Swamp of Virginia-North Carolina; Green Swamp of North Carolina-South Carolina; Little Wambaw of South Carolina; and Okefenokee Swamp of Georgia-Florida. Red maple and swamp black gum predominate in a mixture of many hardwood species; coniferous species found include loblolly and pond pines, and Atlantic white cedar in the north. This category includes the true pocosins of the Carolinas such as White Oak Pocosin in Hofmann Forest.

Wet Flats

Topographically similar to peat swamps and pocosins, wet flats lie in broad interstream Coastal Plain areas where drainage systems are poorly developed. However, they are better drained than their associates because of slightly higher elevation. The nonalluvial soils may possess some accumulation of organic matter, but fertility is superior to peat swamps and pocosins because of superior parent material. Abandoned rice fields of the southern Lower Coastal Plain often fall in this category, as do the Jordan and J and W pocosins in North Carolina. Species generally encountered include (1) on wetter portions--pond pine; sweetgum; black gum; red maple; water, laurel and willow oaks; ash; elm and other species; (2) on "islands" with better drainage--loblolly pine; cherrybark, Shumard and swamp chestnut oaks; yellow-poplar; hickories, and occasionally beech. (Locally, in the North Coastal Plain, wet flats are known as "pocosins," whereas in the South Coastal Plain they are called "hammocks.")

Red River Bottom

These Coastal Plain sites include the floodplains of major drainage systems originating in the Piedmont or mountains. Immediately adjacent to the drainage system, sloughs or oxbows are commonly found which may be classified as muck swamps. Organic matter may accumulate on these clay soils which support water tupelo primarily but also cypress, red maple, swamp black gum,

swamp cottonwood, laurel oak and others. Beyond the sloughs and oxbows are found first bottoms (low ridges) which flood periodically to considerable depths. However, drainage is fairly rapid because of higher elevation. Soils are loam or silt loam. Species include sweetgum; willow, water, laurel and overcup oaks; green ash; water hickory; sycamore; red maple, river birch and elms. At still higher elevation, second bottoms and terraces (high ridges and fronts) are found. Here flooding is infrequent or rare, and more mesophytic species including cherrybark, swamp chestnut and white oaks; hickories, beech and occasionally yellow-poplar occur. Examples of red river bottoms are Roanoke River--Virginia, North Carolina; Santee-South Carolina; Oconee-Georgia; and the Alabama River--Alabama.

Black River Bottom

These sites include the floodplains of major drainage systems originating within the Coastal Plain. Classification of minor site variations and species composition is similar to red river bottoms, with the exception that muck swamps are more prevalent and first and second bottoms and terraces are on a more modest scale. Examples of Black River Bottoms are Blackwater--Virginia; Waccamaw--North Carolina, South Carolina; Black--South Carolina; and St. Mary's--Georgia and Florida.

Branch Bottom

Branch bottoms include relatively flat, alluvial Coastal Plain land along minor drainage systems which are subject to infrequent overflow. On wetter portions with heavier soils, the predominant species are sweetgum; swamp black gum; red maple, willow, water and laurel oaks; and ash. The lighter soils of second bottoms and terraces support sweetgum; cherrybark, Shumard, swamp chestnut and white oaks; hickory; yellow-poplar; and loblolly pine. Small sloughs and oxbows along the main channel support tupelo and swamp black gum. The Big Swamp, North Carolina, is an example of a branch bottom.

Piedmont and Mountains

Bottomland

These areas occur in the Lower Piedmont, where conditions similar to Coastal Plain red river bottoms are encountered. However, upstream sloughs, oxbows and first bottoms decrease in frequency and area until only well-drained bottomland (second bottom and terrace) is encountered. This type also describes the area adjacent to tertiary streams of the red rivers. Species found here include sweetgum; yellow-poplar; green ash; sycamore; cottonwood; water and willow oak; loblolly pine and others.

Coves, Gulfs and Lower Slopes Adjacent to Streams

This Upper Piedmont and Mountain site type is characterized by uneroded, fertile, mineral soils that are moist and well-drained. In the Cumberland Plateau range, hollows extending from the crest of the ridge to major drainage systems, known as gulfs, are characterized by plateaus that are separated by steep terrain. These sites support a mixed mesophytic forest predominantly of yellow-poplar; sweetgum; northern red and black oak. Black cherry, white ash, black walnut and other valuable species are also found on these sites.

Upland Slopes and Ridges

Upland slopes and ridges in the Piedmont and Mountain provinces support a considerable hardwood forest. Here the mineral soils are thinner and drier than the coves and lower slopes. White oak, black and scarlet oaks, and hickory predominate but yellow-poplar and black gum are also common, as well as shortleaf and Virginia pines.