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DIAMETER-HEIGHT-BIOMASS RELATIONSHIPS FOR QUERCUS AND CARYA IN POSEN WOODS NATURE PRESERVE

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ABSTRACT

Diameter and height were measured on 139 trees of *Quercus stellata*, *Q. velutina*, *Q. alba*, and *Carya* in Posen Woods Nature Preserve, Washington County, Illinois. These data were graphed by species and free-hand curves drawn to obtain an average height at 5 cm diameter intervals; species curves were developed for each of three habitat types. Total tree green weight was obtained for each diameter and height from existing biomass tables. These data were converted to dry weight using a conversion factor that ranged from 0.60 to 0.61 for *Quercus* and from 0.64 to 0.68 for *Carya*. A table listing dry weight (kg) by diameter, height and species for each habitat type is presented.

INTRODUCTION

An increasing demand for wood, escalating costs of wood products and concern about sources of energy have generated considerable interest in measuring tree and forest biomass. Information on biomass can be used in harvesting operations when logs are sold by weight, in site evaluation, and in research on nutrient recycling and ecosystem structure. Such studies often provide data and information that can be used to improve forest management and maintain site quality.

One important aspect of structure is the tree diameter-height-biomass relationship. This relationship can be readily studied in mature forest where there has been no major disturbance to influence tree growth and development. The results of a

study on tree diameter, height and biomass in Posen Woods Nature Preserve are reported in this paper.

THE STUDY AREA

Posen Woods is a 16 ha, relatively undisturbed old growth forest located on the Southern Till Plain region in Washington County, Illinois. The Nature Preserve contains one of the best remaining post oak (*Quercus stellata*) flatwoods in a region where this community type originally may have occurred on 10 percent or more of the land area.

The soil of Posen Woods is derived from loess and has a well-developed claypan or fragipan that restricts drainage particularly on level topography. As the name implies, the post oak flatwoods community, in the past called "post oak flats or hickory flats" (Univ. Ill. 1926), is found primarily on extremely level land surfaces (slope <1%) where the Wynoose soil type occurs. This soil is classed as a fine, montmorillonitic, mesic, Typic Albaqualf, and has a nearly impervious claypan that is extremely hard and brittle when dry. Iron and manganese concretions occurring throughout the profile are the basis for the name "buckshot" soil (Univ. Ill. 1926). In Washington County, the Wynoose soil type occupies 12.2 percent or 17,500 ha (Univ. Ill. 1937). Bluford is a closely related soil type in the Till Plain region (U.S.D.A. 1964, 1972) and the flatwoods community also may have been found on the more level surfaces of this soil.

In Posen Woods, the area of Wynoose soil can be divided into two drainage phases corresponding to two community types, henceforth called habitat types. The *Quercus stellata-Cinna arundinacea* (QUST-CIAR) type is found on a site classed as very poorly-drained. Here, *Quercus stellata* is the single dominant species in the cathedral-like overstory. *Cinna arundinacea* is a conspicuous grass in an understory that has a low density of seedlings, saplings, and shrubs. This type covers an area of approximately 2 ha.

The *Quercus stellata-Carya-Toxicodendron radicans* (QUST-CA-TORA) habitat type is found on the poorly-drained phase of the Wynoose soil. *Quercus stellata*, *Q. velutina* and *Carya* are common overstory trees, however, there are areas where *Q. velutina* does not occur. The understory is characterized by a dense stratum of *Carya* seedlings and saplings; *Toxicodendron radicans* is a scattered understory shrub; *Cinna* is absent. This community occupies an area of about 8.0 ha.

The *Quercus alba-Quercus velutina-Toxicodendron radicans* (QUAL-QUVE-TORA) habitat type is restricted to the Ave soil type which covers an area of about 6 ha. This soil is moderately well-drained, has a fragipan at a depth of approximately 60 cm and is located on the slopes of shallow drainages; the soil is classed as a fine-silty, mixed, mesic, Typic Fragiudalf. Woody species found in this community include *Quercus rubra*, *Q. stellata*, *Carya ovata*, *C. glabra*, *C. ovalis*, *C. tomentosa*, *Ulmus americana*, *Juglans nigra* and *Morus rubra*.

METHODS

Diameter (DBH) and height were measured on 27 *Quercus stellata* trees in the QUST-CIAR habitat type, 25 *Quercus stellata* trees in the QUST-CA-TORA type,

and 30 *Quercus alba* trees in the QUAL-QUVE-TORA type; 26 *Quercus velutina* trees and 31 *Carya* trees were measured in the QUST-CA-TORA and QUAL-QUVE-TORA types. For each species, measured trees ranged in diameter from approximately 15 cm to the maximum found in Posen Woods. Data for each species were plotted on graph paper, free-hand curves drawn, and an average height obtained at 5 cm diameter intervals beginning with a 15 cm diameter (*i.e.*, 15, 20, 25 cm, etc.). Total stem green (wet) weight for stem diameter and average height by species were obtained from tables developed by Myers, Polak, Raisanen, Schlesinger, and Stortz (1979). These data were converted to total stem dry weight based on the proportion of wet to dry weight of trees studied by the Tennessee Valley Authority (1972, 1978) and by Dr. H.V. Wiant (West Virginia University, Unpublished data). Conversion values ranged from 0.60 to 0.61 for *Quercus* and from 0.64 to 0.68 for *Carya* depending on diameter and height.

RESULTS AND DISCUSSION

The diameter-height relationship for *Quercus stellata* on the QUST-CA-TORA habitat type is shown in Figure 1. The data show that height increases with diameter but at a slowly decreasing rate up to a diameter of approximately 50 cm. Thereafter, tree height appears to decline slightly after reaching a maximum height of 26 m. The reduction in total height probably was caused by the development of the largest, and presumably oldest, trees in more open (high light) conditions which permitted an increase in lateral growth accompanied by a reduced height growth. Trees smaller than 50 cm probably developed under more dense forest conditions.

In contrast, height growth ceases early and maximum tree height is only 22 or 23 m in the QUST-CIAR habitat type (Fig. 2). No apparent height growth occurs on trees larger than 30 cm. Several interacting causes may be cited for the limited height growth on this habitat type. A shallow claypan, lack of topographic relief and distance from a drainage system make the soil very poorly drained in the spring. Limited root distribution within the pan and low amounts of rainfall later in the growing season combine to make this soil moderately to extremely droughty by mid-summer. It is suggested that *Quercus stellata* is more tolerant of these seasonal soil moisture extremes than other *Quercus* and *Carya* species; hence, it forms a nearly pure stand although its growth rate is reduced compared to that of stems on the QUST-CA-TORA habitat type. Also, the QUST-CA-TORA type, which surrounds the QUST-CIAR type, is located closer to stream drainages and may be better drained in the spring when most growth occurs.

Another difference in the soils of the two habitat types is the penetrability of the subsurface horizons. While additional study is needed to evaluate the possible implications of this factor, observations indicate that a soil probe does not easily penetrate beyond depths of 15 cm and 20 cm in the QUST-CIAR and QUST-CA-TORA habitat types, respectively.

In contrast to the variation in the diameter-height relationship of *Quercus stellata* in two habitat types, *Quercus velutina* has a consistent pattern in both the QUST-CA-TORA and QUAL-QUVE-TORA habitat types (Fig. 3). It appears that a maximum height of approximately 27 m is reached at a diameter of 60 to 65 cm. Thereafter, height appears to remain constant.

The pattern for *Quercus alba* on the QUAL-QUVE-TORA habitat type (Fig. 4) is similar to that for *Quercus velutina*. For diameters less than 30 cm, *Q. velutina* stems have slightly greater heights. Beyond 55 cm, *Q. alba* has a greater height for a given diameter. Height continues to increase with diameter up to 75 cm; maximum height on the QUAL-QUVE-TORA habitat type probably is near 30 m with diameters of approximately 85 to 90 cm. This habitat type is found primarily on the Ava soil type where a fragipan at 60 cm is sufficiently deep to allow for adequate water storage and good to excellent tree growth.

The density of individual *Carya* species is low, but collectively, the species are a substantial component of the QUST-CA-TORA and QUAL-QUVE-TORA types. Data from all species were used to develop a single curve because differences between individual curves were small and low numbers of data points prevented the development of reliable curves.

The curve for the various species of *Carya* (Fig. 5) shows that they have a greater height for a given diameter than any *Quercus* species. Its maximum height appears to be near 30 m, about the same as that of *Quercus alba*. However, this height is reached when the diameter is only 60 to 70 cm, while in *Q. alba* stems, the diameter is likely to be in the range of 85 to 90 cm. The result is that *Carya* would tend to have a greater biomass at a given diameter than would *Quercus*.

Examining the diameter-height relationships in the context of age provides a different perspective. While the diameter-height curves are similar for several of the species, their growth rates differ appreciably. Data for *Carya* in the QUST-CA-TORA and QUAL-QUVE-TORA habitat types show that it is taller for a given diameter than *Quercus stellata*, *Quercus alba*, and *Quercus velutina*, although maximum height is likely to be the same as *Q. alba* (30 m). These data could be interpreted to indicate that *Carya* has a faster volume growth than do *Q. alba* or *Q. velutina*; however, these data are misleading. Tree cores show that both *Carya* and *Quercus* stems were established between 1845 and 1855. The largest *Q. alba* and *Q. velutina* are now 60 to 75 cm in diameter while the largest *Carya* are only 50 to 60 cm. *Quercus stellata* stems in the QUST-CA-TORA habitat type have about the same diameter range as *Carya*, but on the QUST-CIAR type, *Q. stellata* are 5 to 10 cm smaller.

Dry weight biomass (kg) estimates by diameter and average height for *Quercus alba*, *Quercus velutina*, and *Carya* and for *Quercus stellata* on two habitat types are listed in Table 1. These data may be converted to wet weight by multiplying by a factor of 1.64 for *Quercus* and 1.56 for *Carya*.

The average height for a given diameter obtained from the curves show that the trees of Posen Woods are in the middle of the height range delineated by Myers et al. (1979) although their data were collected in the unglaciated Shawnee Hills region of southern Illinois. While the data on diameter-height-biomass relationships presented here will be used to study the productivity of the community on each habitat type in Posen Woods, they also may be applicable to other forests in Illinois.

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Table 1. Average height and dry weight by diameter for *Quercus stellata*, *Quercus velutina*, *Carya* and *Quercus alba* in three habitat types in Posen Woods Nature Preserve. Weight is rounded off to the nearest kilogram.

	QUST-CIAR		QUST-CA-TORA		QUST-CA-TORA & QUAL-QUVE-TORA				QUAL-QUVE-TORA	
	Quercus stellata		*Quercus stellata*		*Quercus velutina*		*Carya species*		*Quercus alba*	
DBH (cm)	Ht. (m)	Wt. (kg)	Ht. (m)	Wt. (kg)	Ht. (m)	Wt. (kg)	Ht. (m)	Wt. (kg)	Ht. (m)	Wt. (kg)
15	12.2	95	15.5	96	13.0	76	10.5	95	11.5	92
20	15.8	204	17.7	206	15.7	174	14.5	254	14.5	196
25	19.2	367	19.6	371	18.0	324	18.5	447	17.0	346
30	21.5	571	21.4	571	19.8	511	21.5	753	19.4	554
35	22.7	858	23.3	862	21.4	806	24.0	1050	21.5	830
40	23.0	1159	24.2	1189	23.0	1131	26.0	1451	22.8	1159
45	23.2	1506	25.8	1581	24.2	1529	27.5	1850	24.3	1545
50	23.2	1904	26.2	2020	25.3	2008	28.5	2350	25.4	1998
55	23.2	2353	25.0	2440	26.2	2601	29.5	2809	26.5	2526
60			21.6	2767	26.7	3109	30.0	3300	27.3	3130
65					26.8	3699			28.2	3818
70					26.7	4289			28.9	4500
75					26.5	4500			29.5	5300

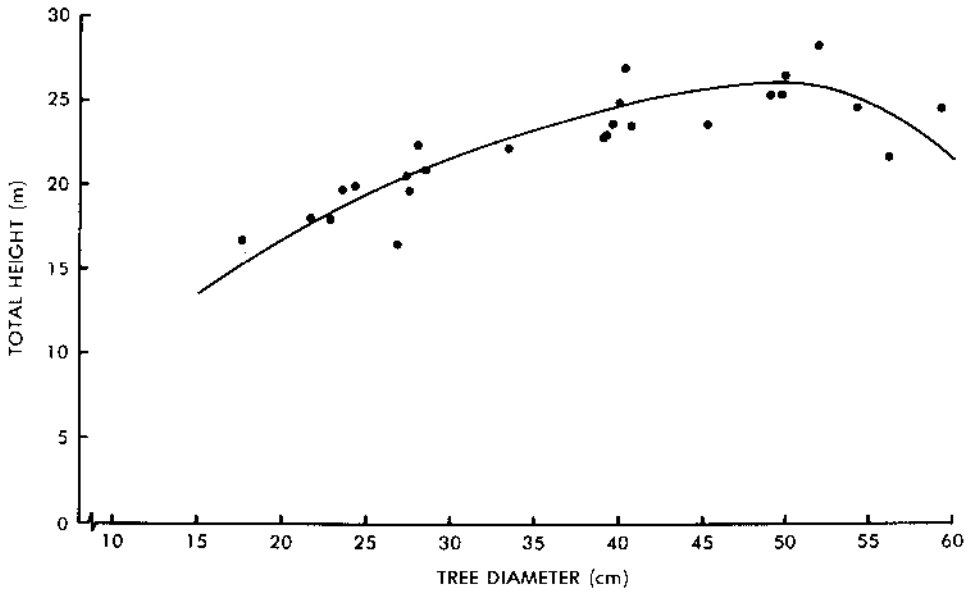

Figure 1. Diameter-height relationship for *Quercus stellata* in the QUST-CA-TORA habitat type in Posen Woods Nature Preserve.

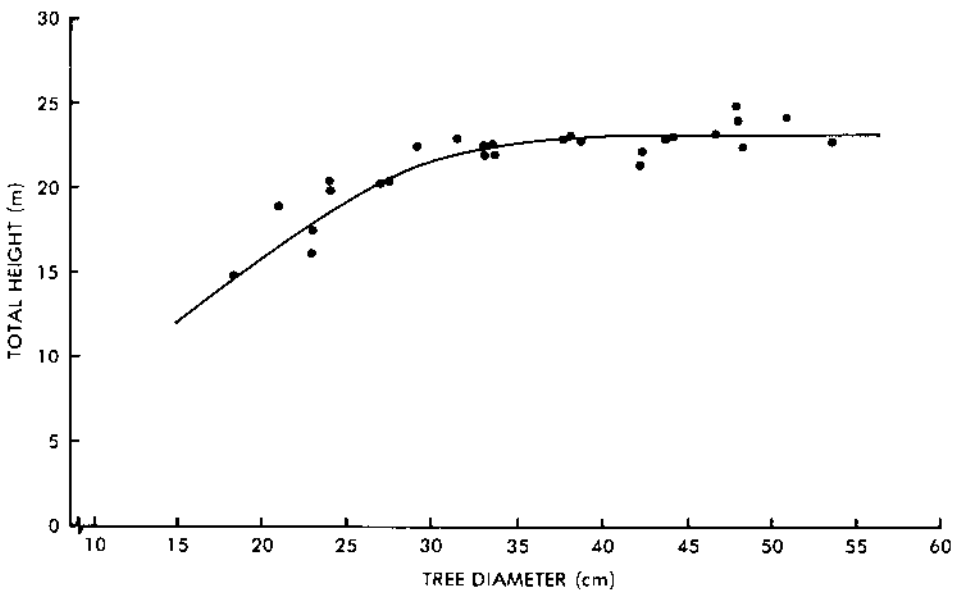

Figure 2. Diameter-height relationship for *Quercus stellata* in the QUST-CIAR habitat type in Posen Woods Nature Preserve.

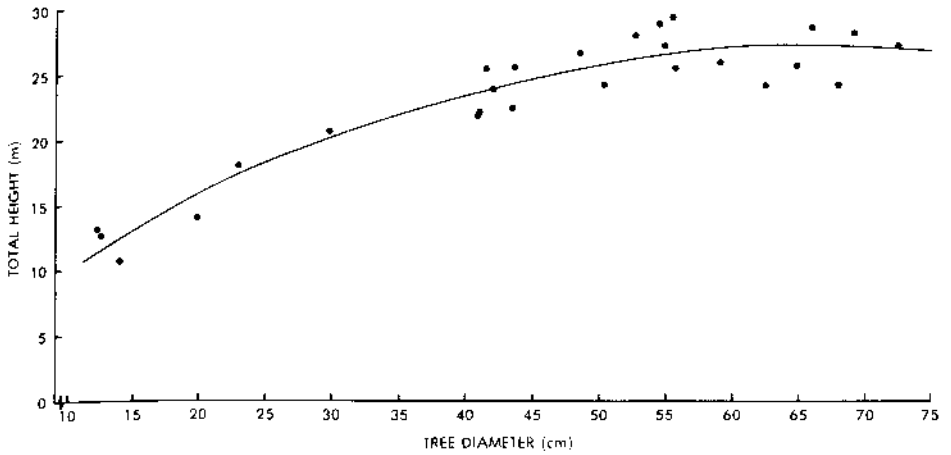

Figure 3. Diameter-height relationship for *Quercus velutina* in Posen Woods Nature Preserve.

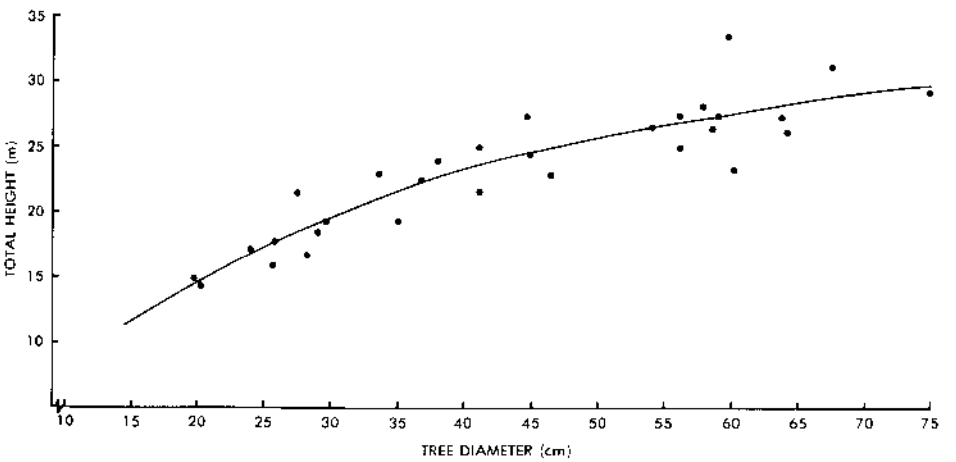

Figure 4. Diameter-height relationship for *Quercus alba* in Posen Woods Nature Preserve.

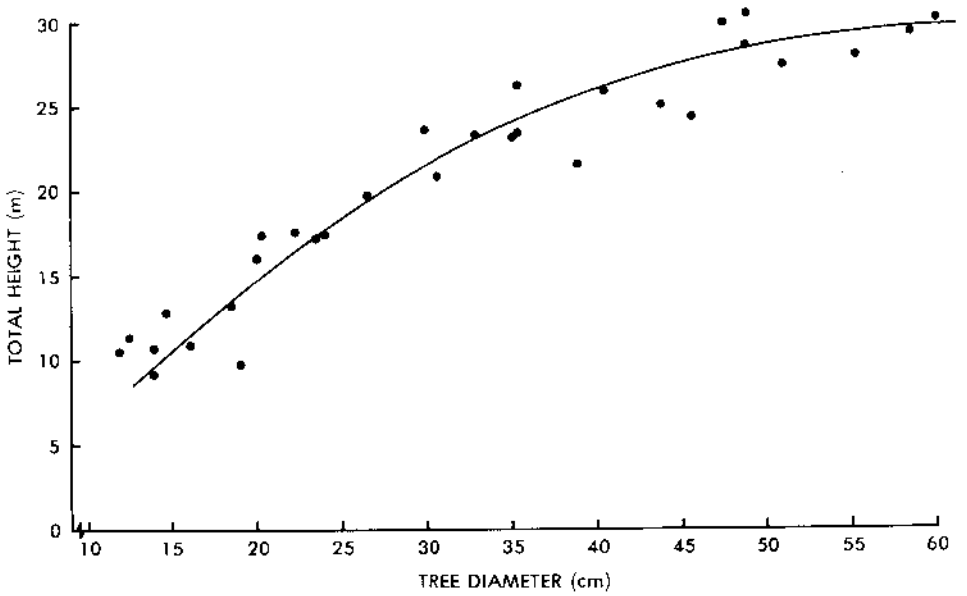

Figure 5. Diameter-height relationship for *Carya* in Posen Woods Nature Preserve.