USDA FOREST SERVICE
RESEARCH PAPER NC-160

SITE INDEX CURVES for northern hardwoods in northern wisconsin and upper michigan

Willard H. Carmean

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

North Central Forest Experiment Station
John H. Ohman, Director
Forest Service—U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108

Manuscript approved for publication September 26, 1977

1978

SITE INDEX CURVES FOR NORTHERN HARDWOODS IN NORTHERN WISCONSIN AND UPPER MICHIGAN

Willard H. Carmean, *Principal Soil Scientist, St. Paul, Minnesota*

Northern Hardwoods are among the more important and widespread forest types found in eastern hardwood forests and cover about 10 million acres in the Lake States (USDA Forest Service 1973). Characteristic species are sugar maple[1] (*Acer saccharum* Marsh.), red maple (*A. rubrum* L.), and yellow birch (*Betula alleghaniensis* Britton). In certain areas American beech (*Fagus grandifolia* Ehrh.), American basswood (*Tilia americana* L.), American elm (*Ulmus americana* L.), and white ash (*Fraxinus americana* L.) are important stand components. Other species that occur less frequently in northern hardwood stands are black ash (*F. nigra* Marsh.), black cherry (*Prunus serotina* Ehrh.), northern red oak (*Quercus rubra* L.), paper birch (*B. papyrifera* Marsh.), bigtooth aspen (*Populus grandidentata* Michx.), and quaking aspen (*P. tremuloides* Michx.).

One of the first steps for intensively managing forests is to determine the site quality of the land for different tree species. The site index method is the most widely accepted means for estimating site quality in the United States and Canada (Carmean 1975, 1977). This method of site evaluation requires (a) suitable trees for the needed height and age measurements, and (b) accurate site index curves applicable to local soil and site conditions.

Satisfactory site index estimates can be taken only from dominant and codominant trees that have been free-growing and uninjured throughout their lives. Such trees are most commonly found in even-aged, fully stocked stands that have not been disturbed by past harvesting, repeated burning, or heavy grazing. In the Lake States the original northern hardwood stands were usually uneven in age. Dominant and codominant trees in these old growth stands generally are unsuited for site evaluation because they originated as understory trees, and thus have been subjected to periods of suppression. However, extensive stands of young, even-aged northern hardwoods also occur in the Lake States; they originated after clearcutting or heavy harvest cutting 40 or more years ago. Dominant and codominant trees in such stands are well suited for site index estimation.

Accurate site index curves are lacking for most of the species found in the Lake States northern hardwood forests (Carmean 1977). For many species existing site index curves are based on limited data collected from other regions, or are older harmonized curves not based on precise stem analysis methods. The goal of this study was to construct site index curves suitable for accurate site quality estimation for 13 tree species commonly found in the northern hardwood stands of the Lake States.

THE DATA

Data were collected from 204 plots located in northern Wisconsin and Upper Michigan (fig. 1). Most plots were located on the Chequamegon, Nicolet, Ottawa, and Hiawatha National Forests, but several were located on nearby State and private land.

All plots were approximately 1/5-acre in size and were established in fully stocked, even-aged northern hardwood stands that were between 41 and 105 years of age; dominant and codominant trees on each plot had an age range of no more than 10 years. Several tree species usually occurred on each plot, and for each species one to six dominant and codominant trees were used to estimate site index. Each tree selected for site

[1] *Tree names follow Little (1953).*

determination was felled and the bole was sectioned at about a 6-inch stump height, at 2 feet, at 4.5 feet, and at 4-foot intervals thereafter up the bole. Annual rings were carefully counted on the disks that were cut at each section point.

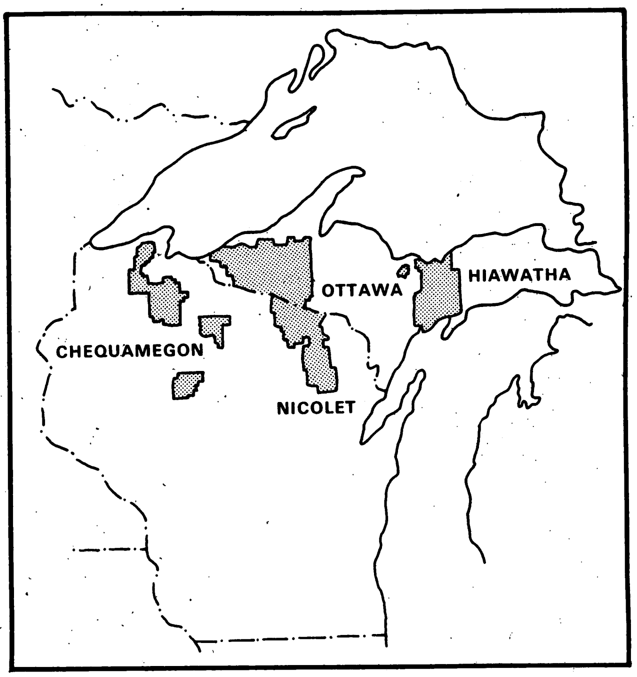

Figure 1.—*Site index curves for northern hardwood species are based on stem analysis data taken from plots located on the Chequamegon, Nicolet, Ottawa, and Hiawatha National Forests of northern Wisconsin and Upper Michigan. Additional plots were located on nearby State and private lands.*

Individual tree height-age curves were plotted using annual ring counts from each section. Trees that showed signs of early suppression, top breakage, or dieback were discarded from the analysis; trees also were discarded if ring counts revealed that they exceeded the defined 10-year range in age for even-aged stands. A total of 3,402 dominant and codominant trees were used for computing site index curves for the 13 hardwood species (table 1).

COMPUTATIONS AND RESULTS

Procedures followed were similar to those used for computing site index curves for upland oaks in the Central States (Carmean 1972, [2]). Briefly, age at breast height (4.5 feet) was used as the starting point for all height-age curves to eliminate the early erratic growth that occassionally occurs. Then age at breast height was converted to total age by adding a constant of 4 years. Tree height-age curves for each species were averaged on each plot, and plots were stratified into 5-foot site index classes (table 1). For each species tree height at successive 5-year intervals was read from the average height-age curves; these are the values used for the subsequent site curve computations. Separate nonlinear height-growth

[2]*Carmean, Willard H. 1978. Site index curves for northern hardwoods in the Lake States. Unpublished manuscript on file at the North Central Forest Experiment Station, St. Paul, Minnesota.*

Table 1.—*Number of plots and trees by site index class used in constructing site index curves for 13 species commonly found in second growth northern hardwood forests of northern Wisconsin and Upper Michigan*

Species	Site index class									Total
	<43	43-47	48-52	53-57	58-62	63-67	68-72	73-77	>77	
	Total number of plots[1]									
Sugar maple	2(9)	8(27)	25(105)	35(139)	54(220)	33(140)	18(76)	2(5)		177(721)
Red maple	1(4)	5(18)	19(77)	22(77)	36(145)	21(77)	9(37)	1(3)		114(438)
Yellow birch	3(9)	3(10)	11(37)	30(116)	38(157)	22(82)	10(42)	2(6)		119(459)
American beech		2(6)	6(23)	7(27)	4(14)					19(70)
American basswood		3(9)	5(17)	14(48)	23(87)	37(154)	31(131)	6(22)	3(15)	122(483)
American elm		3(11)	7(26)	14(52)	24(87)	22(80)	26(107)	12(48)	1(5)	109(416)
White ash		2(7)	2(10)	5(15)	10(35)	18(57)	19(86)	12(50)	5(15)	73(275)
Black ash			4(13)	6(24)	11(39)	6(20)	8(33)	3(13)	1(1)	39(143)
Black cherry	1(3)	2(9)	3(10)	7(19)	5(14)	14(48)	5(12)	4(8)	1(3)	42(126)
Northern red oak			2(3)	3(15)	11(42)	15(49)	5(23)	1(4)		37(136)
Paper birch		1(2)		8(22)	6(18)	7(20)	8(31)			30(93)
Aspens[2]				2(7)	4(13)	2(5)	1(2)	2(5)	2(10)	13(42)
Total	7(25)	29(99)	84(321)	153(561)	226(871)	197(732)	140(580)	45(164)	13(49)	894(3,402)

[1]Numbers in parentheses are the number of trees sectioned.
[2]Data combined for bigtooth and quaking aspens.

regression equations were then computed for each site class. General nonlinear height-growth regression equations combining all data also were computed for the 13 hardwood species using observed tree height and age data and the method of least squares. The resulting equations[2] were used to compute the site index curves for the 13 species (figs. 2-13).

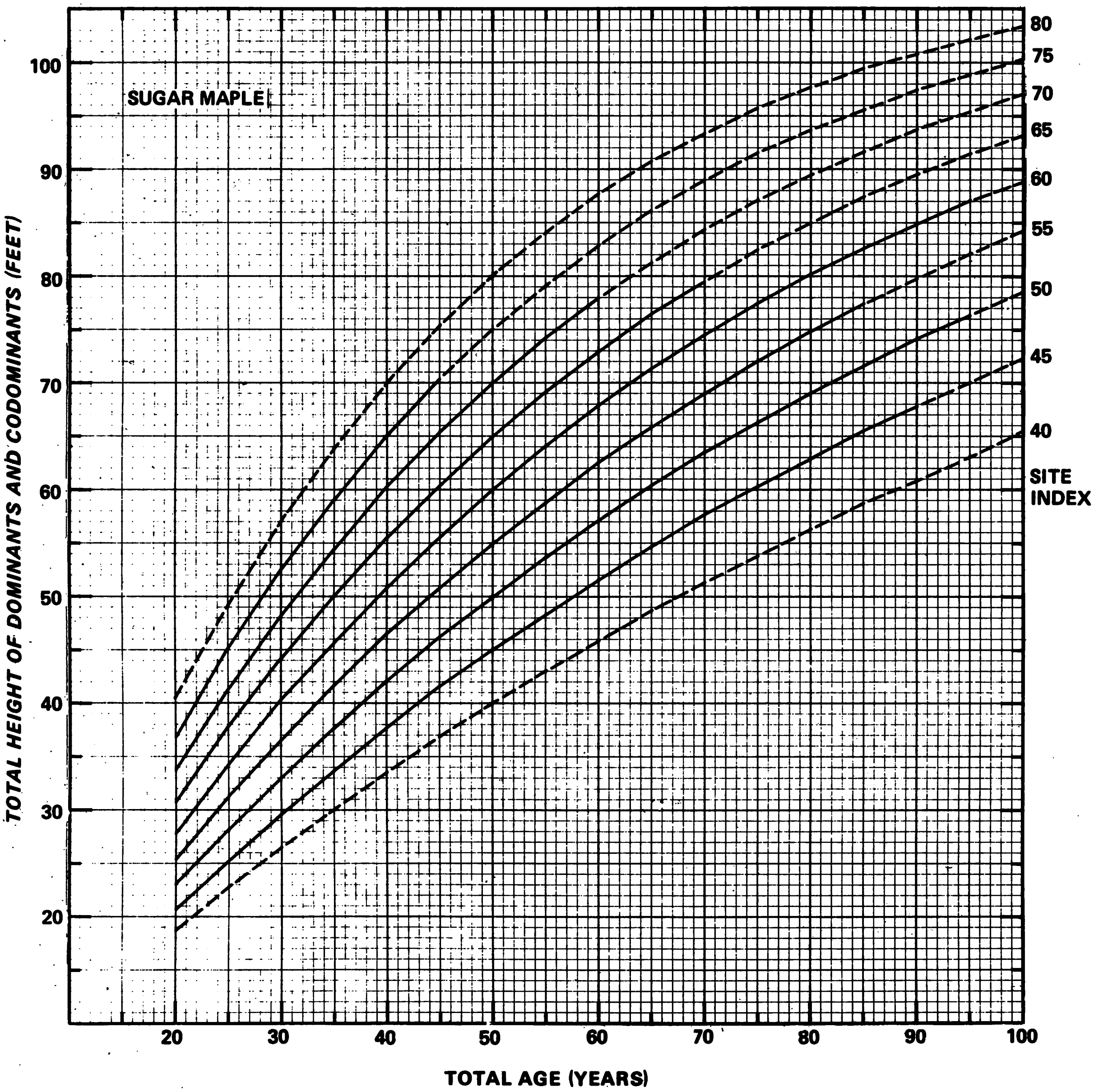

Figure 2.— *Site index curves for sugar maple in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 721 dominant and codominant trees growing in 177 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

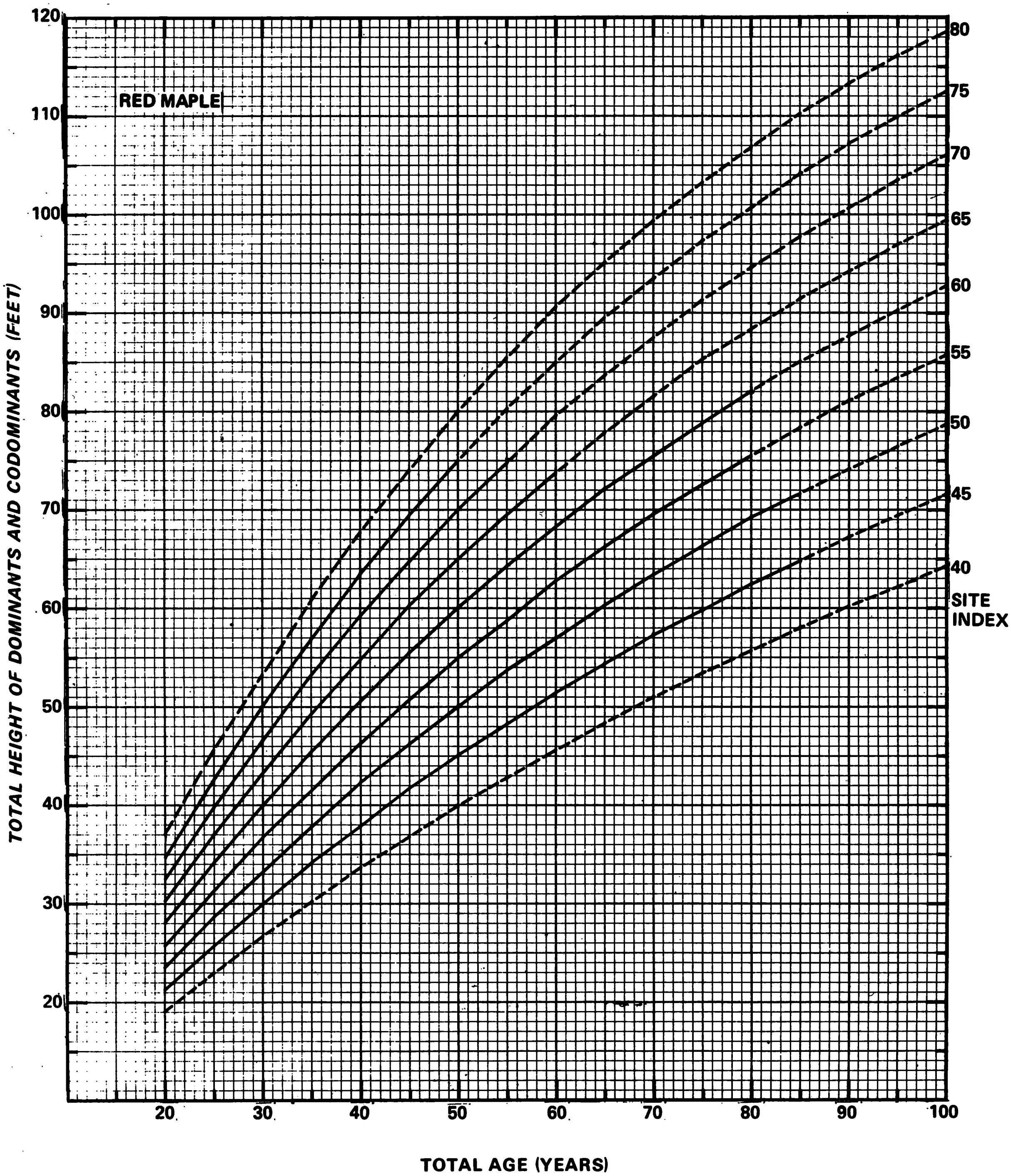

Figure 3.— *Site index curves for red maple in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 438 dominant and codominant trees growing in 114 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

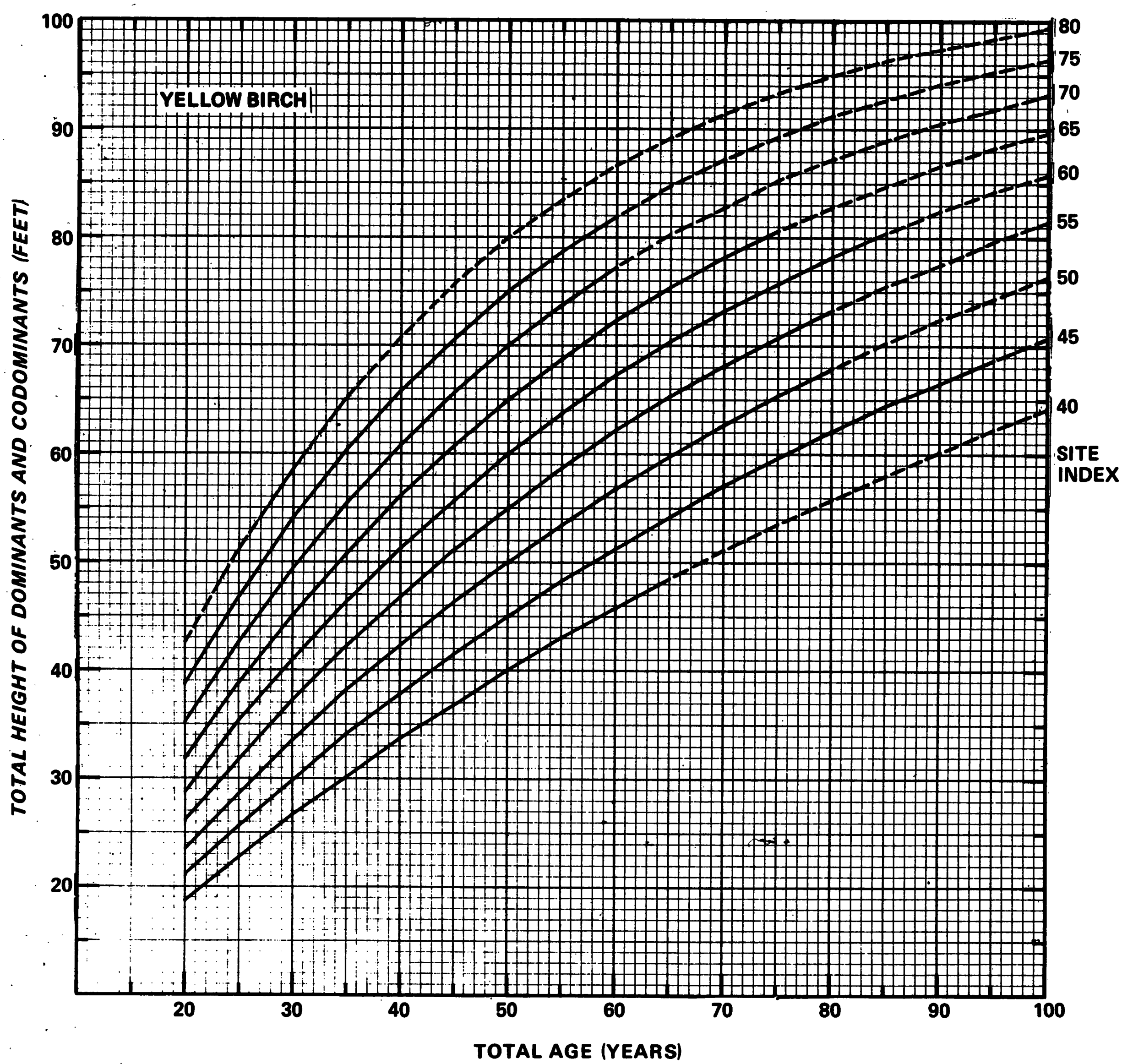

Figure 4.— *Site index curves for yellow birch in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 459 dominant and codominant trees growing in 119 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

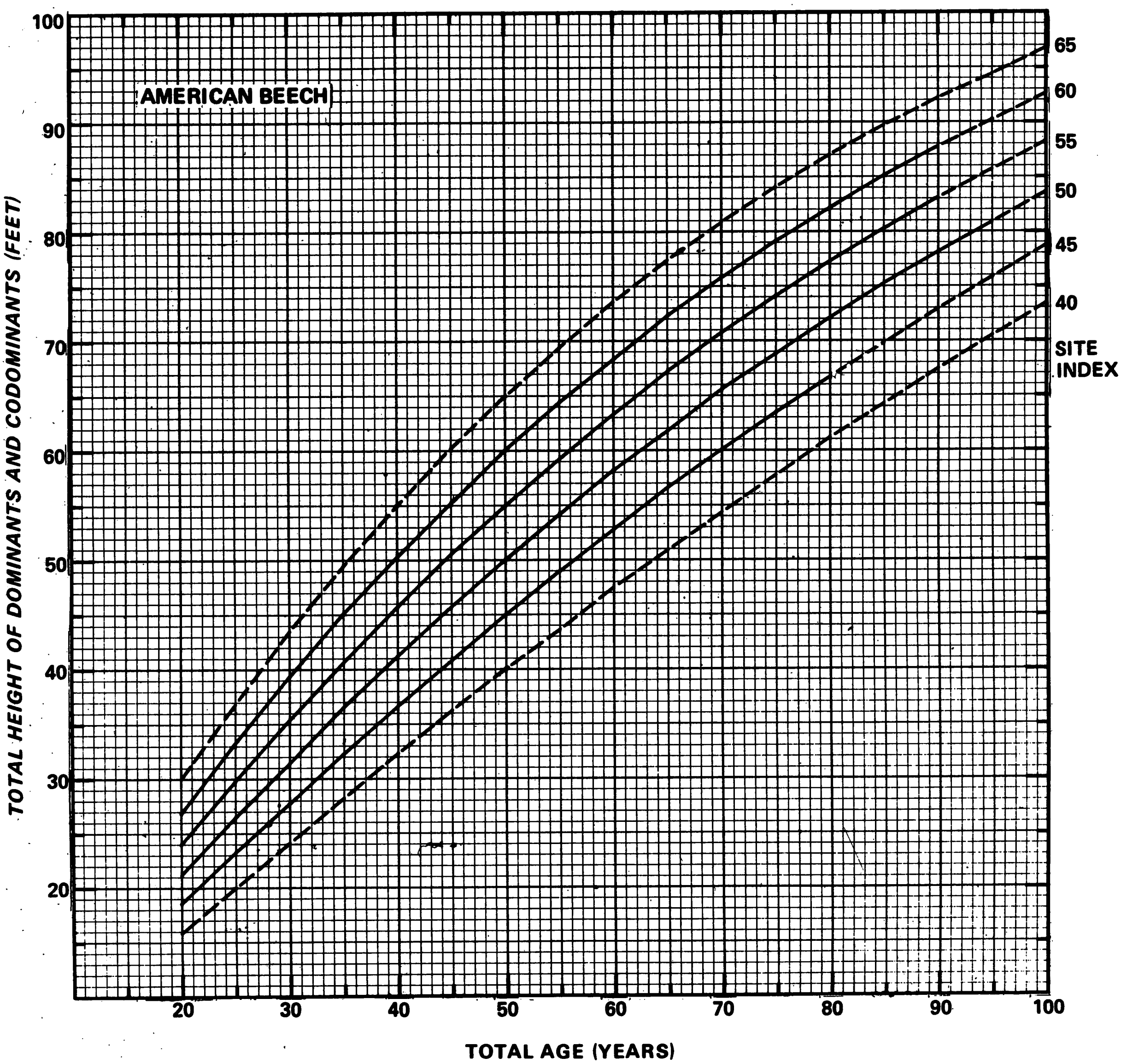

Figure 5.—*Site index curves for American beech in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 70 dominant and codominant trees growing in 19 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

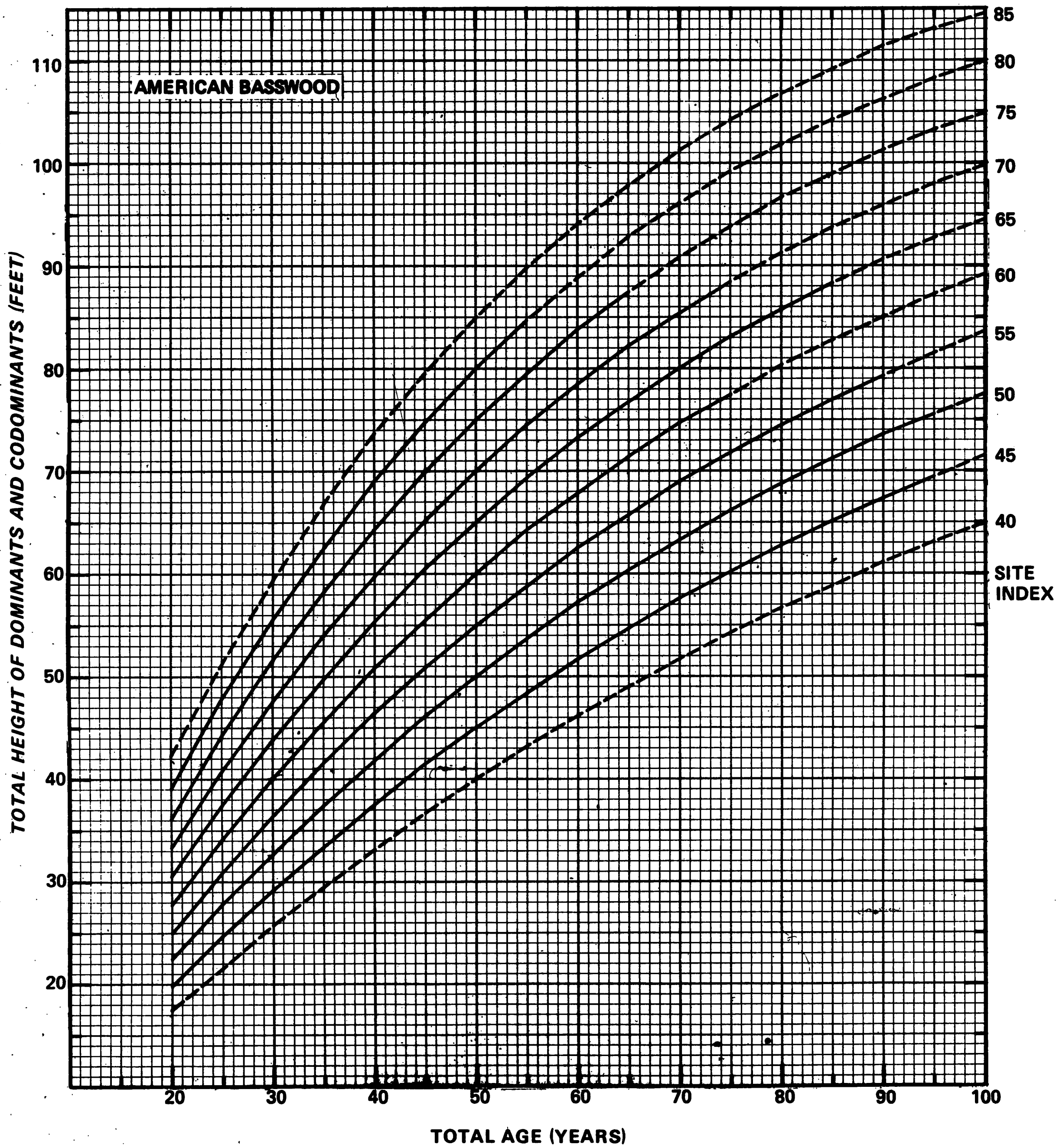

Figure 6.—*Site index curves for American basswood in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 483 dominant and codominant trees growing in 122 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

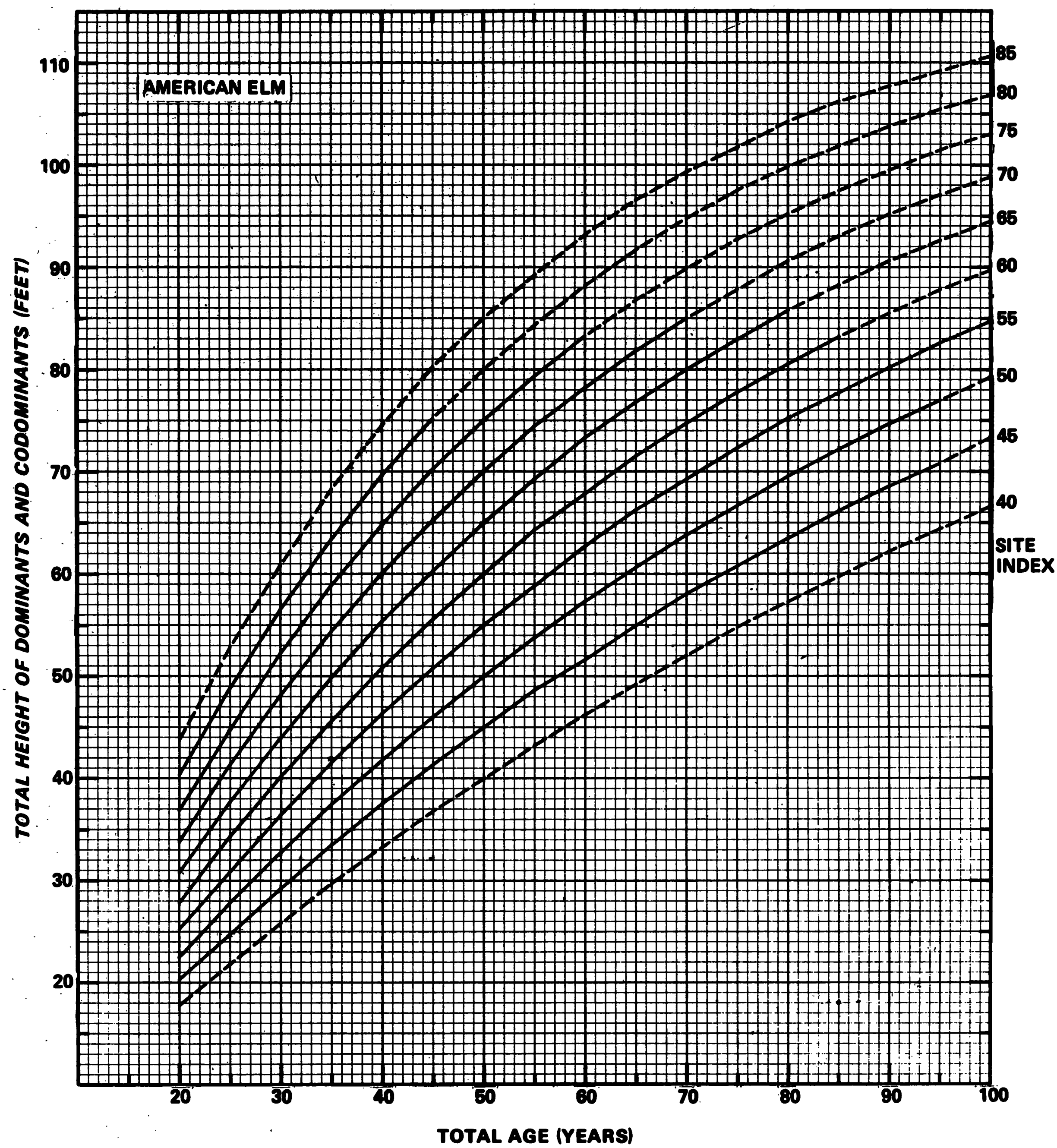

Figure 7.—*Site index curves for American elm in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 416 dominant and codominant trees growing in 109 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

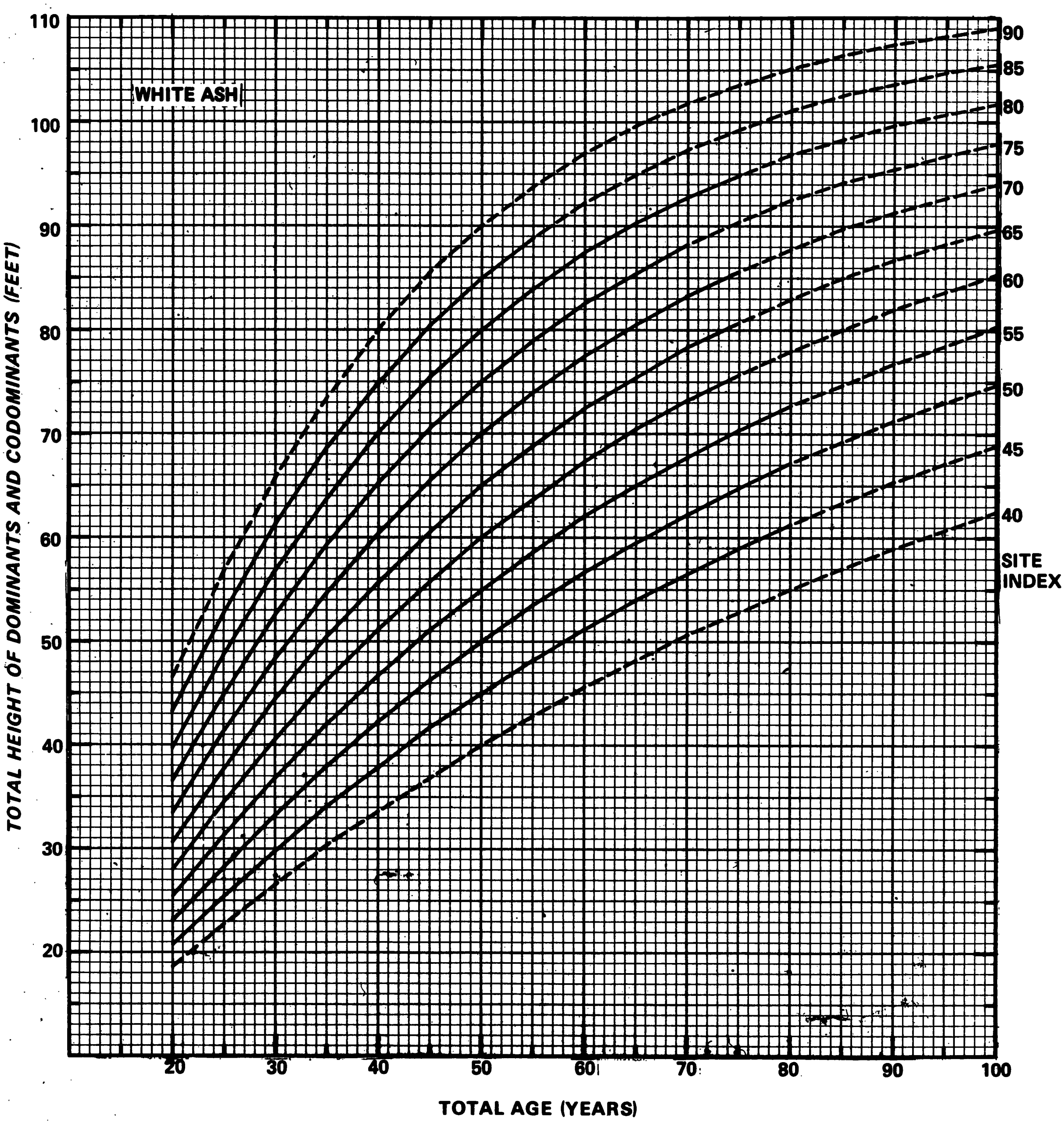

Figure 8.—*Site index curves for white ash in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 275 dominant and codominant trees growing in 73 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

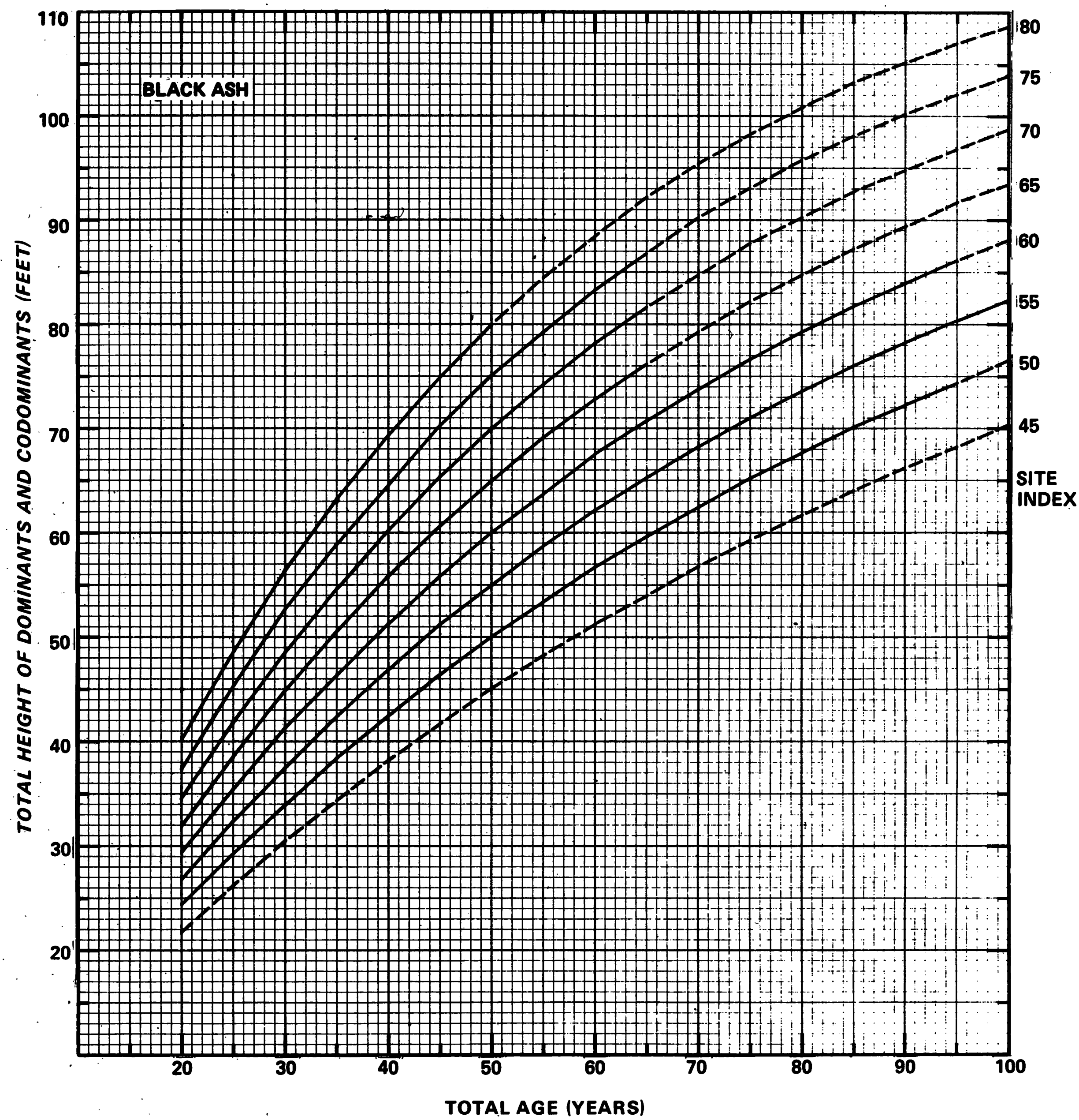

Figure 9.—*Site index curves for black ash in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 143 dominant and codominant trees growing in 39 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

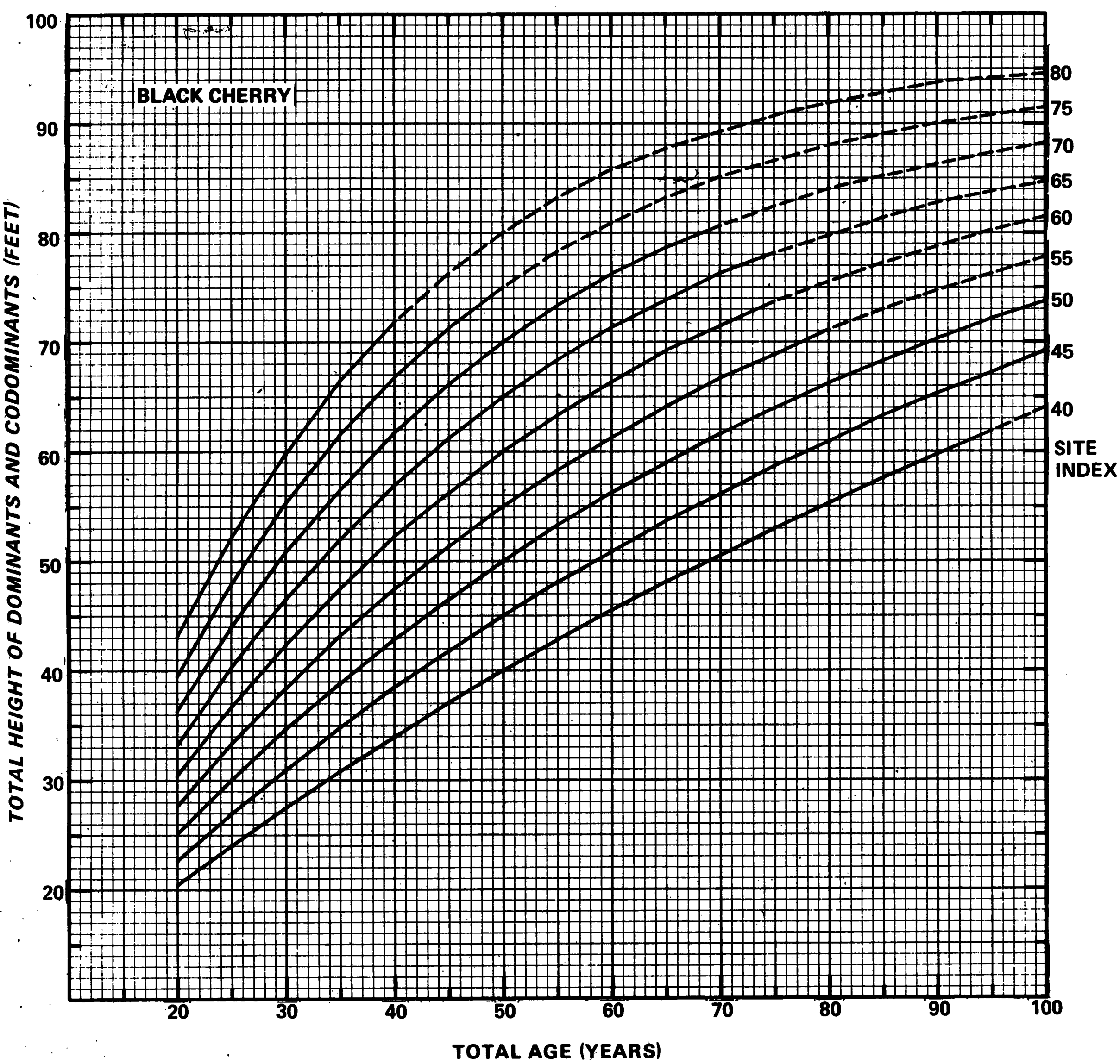

Figure 10.—*Site index curves for black cherry in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 126 dominant and codominant trees growing in 42 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

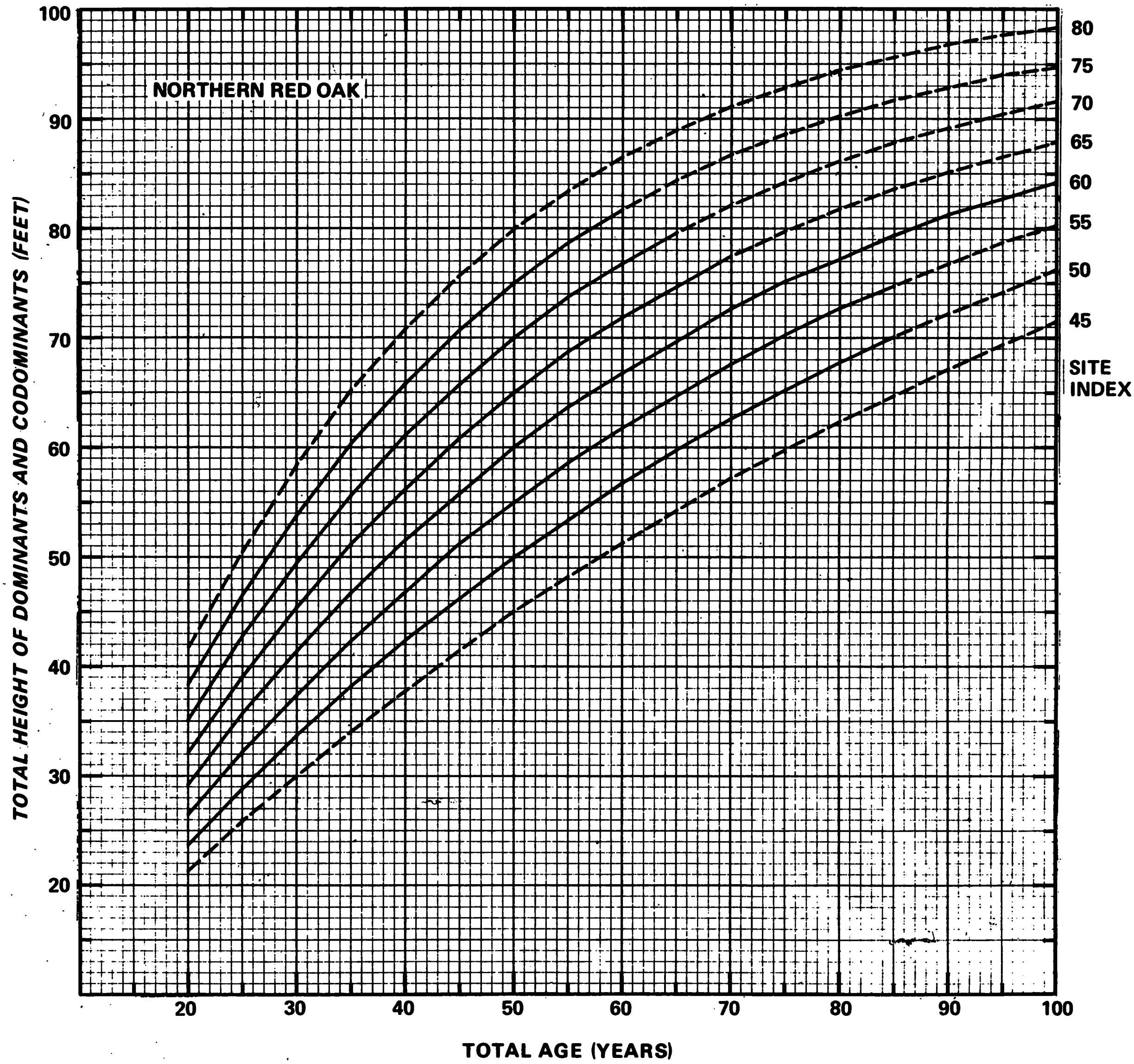

Figure 11.—*Site index curves for northern red oak in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 136 dominant and codominant trees growing in 37 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

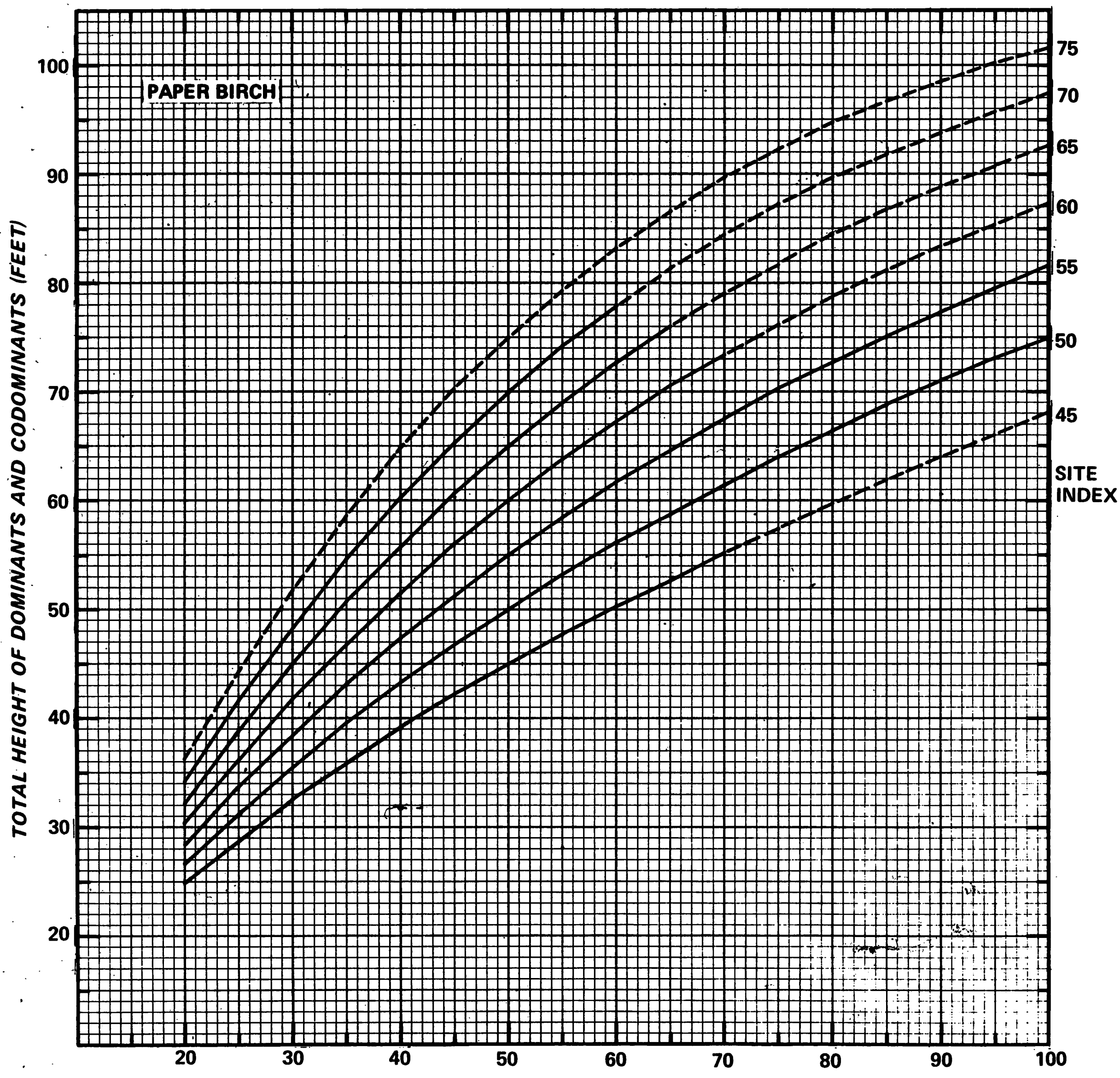

Figure 12.—*Site index curves for paper birch in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 93 dominant and codominant trees growing in 30 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

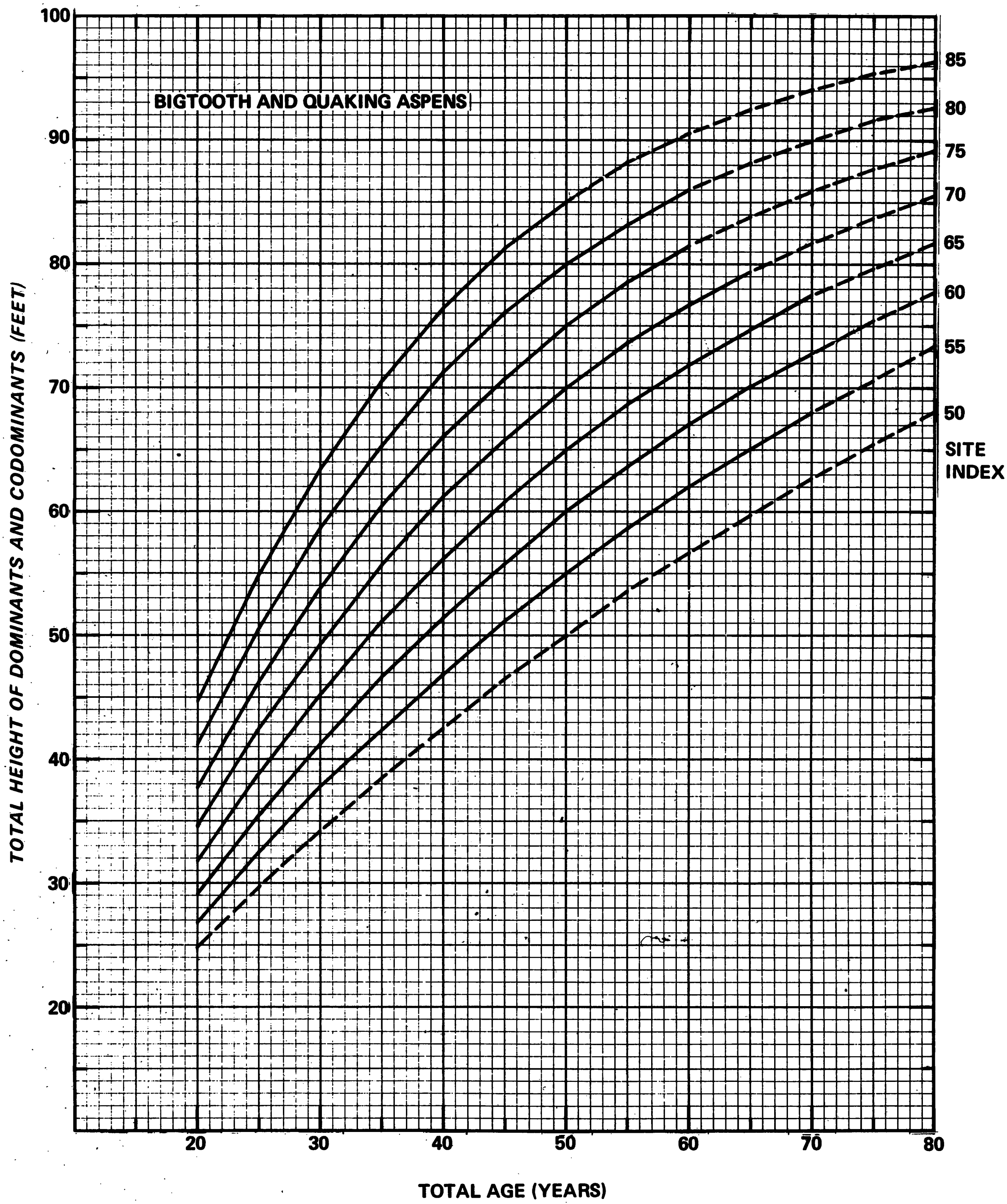

Figure 13.—*Site index curves for bigtooth and quaking aspens in northern Wisconsin and Upper Michigan. These curves are based on stem analyses of 42 dominant and codominant trees growing in 13 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.*

DISCUSSION

One important finding was that height growth patterns differed for each of the species found in even-aged second growth northern hardwood forests. Shapes of height growth curves are similar for most species in early years even though certain species such as basswood, elm, and the ashes have more rapid early height growth. But after 50 years, differences in shapes of curves between species are particularly evident for trees growing on medium and good sites. For example, yellow birch and black cherry have marked slowing of height growth in later years on good and medium sites. In contrast, red maple and American beech maintain height growth better in later years than do other species. Because of these different patterns of later height growth separate site index curves are presented for each of the hardwood species (figs. 2-13).

Another important finding was that for the most species the shape of the height growth curves differ (are polymorphic) for different levels of site quality. Trees on poor sites grow slowly throughout their lives. In contrast, trees on good sites have a surge of rapid early height growth followed by a pronounced slowing of height growth after 50 years.

A third finding was that for most species the site curves I computed differed from other published site index curves (Carmean 1978). However, most of these earlier curves either are older harmonized curves not based on stem analysis methods or they are from regions other than the Lake States.

HOW TO USE THE SITE INDEX CURVES

1. Divide the area for which site estimates are needed into mappable units having similar topography, soil, and site quality. These units may be only a few acres in size for certain research studies where precise site quality estimations are needed, or they may be much larger for certain timber management units where less precise site quality estimations are needed.

2. Locate well-stocked even-aged stands in each unit. Because estimates of site index are more dependable when using trees that are close to index age, these stands should be at least 20 years old and preferably should not be younger than 35 or older than 65 years of age.

3. Select at least three or four well-formed dominant and codominant trees in each stand that have been free growing and uninjured throughout their lives. The number of trees selected depends upon the desired precision of the site index estimates. This precision depends on the variability of the site index estimates among the site trees and also on the variability of the soil and topographic conditions within the mapping unit.

4. Measure total height and take an increment boring at breast height (4.5 feet) to estimate age for each site tree. Reject trees that have narrow annual rings in early years because this indicates early suppression in height growth; also reject trees that are 10 or more years older or younger than the main stand.

Annual rings are easily counted for ring-porous species such as the ashes and red oak. In contrast, annual rings are difficult to count for diffuse-porous species such as the maples, birches, basswood, beech, and the aspens. For these species annual rings are more prominent if increment cores are radially-shaved, moistened, and examined under magnification and strong light. When more accurate age and height estimates are desired, fell several dominant and codominant trees, measure total tree height, then cut a disk at dbh for use in making ring counts. Annual rings on the disks are prominent under magnification and strong light when radial portions of the disk are smoothed using a router, or a high speed electric drill or planer.

5. Use height and total age estimates with the appropriate site index curves (figs. 2-13) to estimate site index for each measured tree. Average the individual tree site indices to obtain a site index estimate for the stand or for the particular land unit.

LITERATURE CITED

Carmean, Willard H. 1972. Site index curves for upland oaks in the Central States. For. Sci. 18:109-120.

Carmean, Willard H. 1975. Forest site quality evaluation in the United States. Adv. in Agron. 27:209-269.

Carmean, Willard H. 1977. Site classification for nothern forest species. *In* Intensive culture of northern forest types. Symp. Proc. U.S. Dep. Agric. For. Serv., Gen. Tech. Rep. NE-29, p. 205-239. Northeast. For. Exp. Stn., Upper Darby, Pennsylvania.

Carmean, Willard H. (In prep.) Comparing and selecting site index curves for northern hardwood species. U.S. Dep. Agric. For. Serv. Res. Pap. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Little, Elbert L., Jr. 1953. Check list of native and naturalized trees of the United States (including Alaska). U.S. Dep. Agric., Agric. Handb. 41, 472 p.

USDA Forest Service. 1973. Silvicultural systems for the major forest types of the United States. U.S. Dep. Agric., Agric. Handb. 445, 114 p.

☆U.S. GOVERNMENT PRINTING OFFICE: 1978—768-713/36

Carmean, Willard H.
1978. Site index curves for northern hardwoods in northern Wisconsin and Upper Michigan. U.S. Dep. Agric. For. Serv. Res. Pap. NC-160, 16 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Site index curves based on stem analyses were computed for 13 species found in even-aged, second growth northern hardwood stands. These curves showed that most species had similarly-shaped height growth curves in early years, but after 50 years differences in both rate and pattern of growth between species was evident for trees growing on medium and good sites. Most species have differently-shaped height growth curves for different levels of site quality.

OXFORD: 541(774/775). KEY WORDS: Site index curves, stem analysis, polymorphic height growth.

Carmean, Willard H.
1978. Site index curves for northern hardwoods in northern Wisconsin and Upper Michigan. U.S. Dep. Agric. For. Serv. Res. Pap. NC-160, 16 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

Site index curves based on stem analyses were computed for 13 species found in even-aged, second growth northern hardwood stands. These curves showed that most species had similarly-shaped height growth curves in early years, but after 50 years differences in both rate and pattern of growth between species was evident for trees growing on medium and good sites. Most species have differently-shaped height growth curves for different levels of site quality.

OXFORD: 541(774/775). KEY WORDS: Site index curves, stem analysis, polymorphic height growth.

Put trash in the proper place.