# 10m Site Class Method

## Forest Biometrics Research Institute

***Valid for All Species and Regions***

**Region / Species Site Classification**
**Corvallis, Oregon**
**March 28, 2007**

## Introduction to the 10m Site Class Method

The Ten-Meter (10m) Site Class method is a new concept developed by the Forest Biometrics Research Institute (FBRI). It has never been described or explored in the forestry literature to date. This paper attempts to describe the objective, method and application of this new method of productivity classification.

If read and absorbed by an open mind, the reader will find that this method is robust, general to all regions and species, and easy to apply. It will replace all current methods based on total or breast height age. It defines the method to determine the natural productivity of any forest bio/geo/climatic region. In other words, this method attempts to classify the macro-site level and distribution of forest productivity independent of all silvicultural or genetic effects.

## Objectives and Justification

This paper provides the methods to accomplish three very critical objectives:

1) Establish and apply a robust method of determining growth (site) capacity from direct tree measurements; and,
2) Develop an ownership-wide (tree farm, forest, watershed, reservation, etc.) classification of native productivity capacity of all lands (as a GIS layer); and,
3) Separate the impact and influence of silvicultural treatments (site preparation, brush control, animal control, nutrient additions), tree species and genetic gains from the underlying natural productive capacity of the edaphic (soils), climatic and topographic characteristics of these forest lands.

This approach removes the current entanglement between *growth acceleration* due to early silvicultural treatments (such as site preparation, brush control and animal browsing) and *growth capacity* defined by soil nutrients, soil depth, precipitation and growing season length.

Most current site classification methods rely on a height over age relationship of healthy trees over an extended period of time. Examples are:

1) historic total age site curves indexed by the total tree height at 100 years of age;
2) conventional West Coast site curves indexed by total height at 50 years of age measured at breast height; and,
3) conventional Southeastern site curves indexed by total height at 25 years of age.

These site curve methods rely on measurements on healthy trees historically grown in natural conditions without significant silvicultural intervention. However, current forest management on most industrial, tribal, county, State and private forest lands has resulted in silvicultural treatments that significantly impact the determination of natural site productivity on much of these lands. Current methods are also confounded by early suppression effects of trees growing under overstory canopies for extended periods of time before the overstory is removed.

The conventional way of determining a reference site index value is to observe the height of a tree at one point, usually total height, and determine its age. As previously mentioned, the standard age used in the Northwest is age at breast height. Age taken at breast height helps by removing irregularities due to early competition from non-tree competitors such as grass, brush and animals. It is also more easily obtained than total tree age. Total height is then looked up in a reference set of height/age tables for each species to determine a site index value (height at fifty years from breast height).

One of the shortcomings of accepting this approach without review is that the reference curve may not adequately represent the height growth development of this species in this geographic area over time. Low sites produce short trees in different regions for different reasons. Height growth may be limited by available moisture, nutrients, growing season or soil depth. Each of these factors affects height development in different ways over the life of a tree. In application, we may observe fast early growth with later slowing in a shallow soil as opposed to moderate growth rates to extended ages in deep nutrient-limited soils. The fact is, that even for a common site index value, the shape of the height/age trend will vary under differing limiting conditions. For example, all published site index curves available in the Northwest have been developed for extensive geographic regions of each species. In every case, each author has relied on the mathematical form of the height/age equation selected to account for differences in shape. Much of the discussion in the forestry literature in the 1960's had to do with the merits of "polymorphic site curves" versus "anamorphic site curves". However, at that time, polymorphism was considered important only between site index levels, not within site index levels. As a result, a low site glacial outwash soil on the Olympic Peninsula was assumed to have the same shape as a low site high elevation soil in the Cascade Mountains.

*Providing for a more universal approach via Zeide's two point system*

To overcome these shortcomings the two-point principle was described and published by Boris Zeide in the 1978 Journal of Forestry. It has been described and applied in the Forest Projection and Planning System (FPS) software package and textbook since 1995. This principle has been applied in the FBRI Regional Species Libraries to assist you in determining both the appropriate site index level and growth type (shape) for each species across the extent of the lands which you manage. Once the forester has determined two significantly different height/age pairs on a given tree; then this principle is sufficient to determine both the appropriate site index growth type and site index level for that tree of any species.

The objective of 10m Site method is to provide a means to permanently assess the natural growth capacity of any given forest stand. The productivity classification of this stand then may be extrapolated to other acreages of similar stratification based on soils, climate and topography. Zeide's two-point principal continues to be the basis upon which the 10m Site method is developed and applied in this paper and in the FBRI Libraries.

Secondary objectives are to incorporate means to separate and define: a) silvicultural treatment effects, b) genetic capacity, and c) regional variations within a species due to the unique growth capacity of each bio/geo/climatic region (think of Douglas-fir from Nanaimo to Arcata to Missoula).

**Approach to Site Productivity Classification**

Tree height growth continues to demonstrate itself as a robust indicator of growth capacity and dynamics. It is relatively insensitive to competition effects once the tree has established itself both in crown and root capacity. Also, the relationship of height to age provides a reasonable time-dependent factor by which foresters may assess the growth and yield capacity on a given piece of ground for a given tree species. Dr. Zeide's two-point principal has provided a standardized method to classify this productivity, both in level and shape of the height / age progression over time.

Any two points and the associated years between these points are sufficient to determine the site classification of any species *given that a series of site curves already exist* for this species. *If we accept the existing site curves*, then total or breast height age is not necessary; only the number of years between the two height measurements is necessary.

The **opportunity** in using two height / age pairs (which are beyond approximately thirty feet in height) is that early silviculture and/or crown suppression has little impact on the determination of site index capacity. This is because total age or breast height age is not used. In fact, the sample tree could be hollow at breast height and the two-point method will still provide a good site classification even though breast height age is un-attainable.

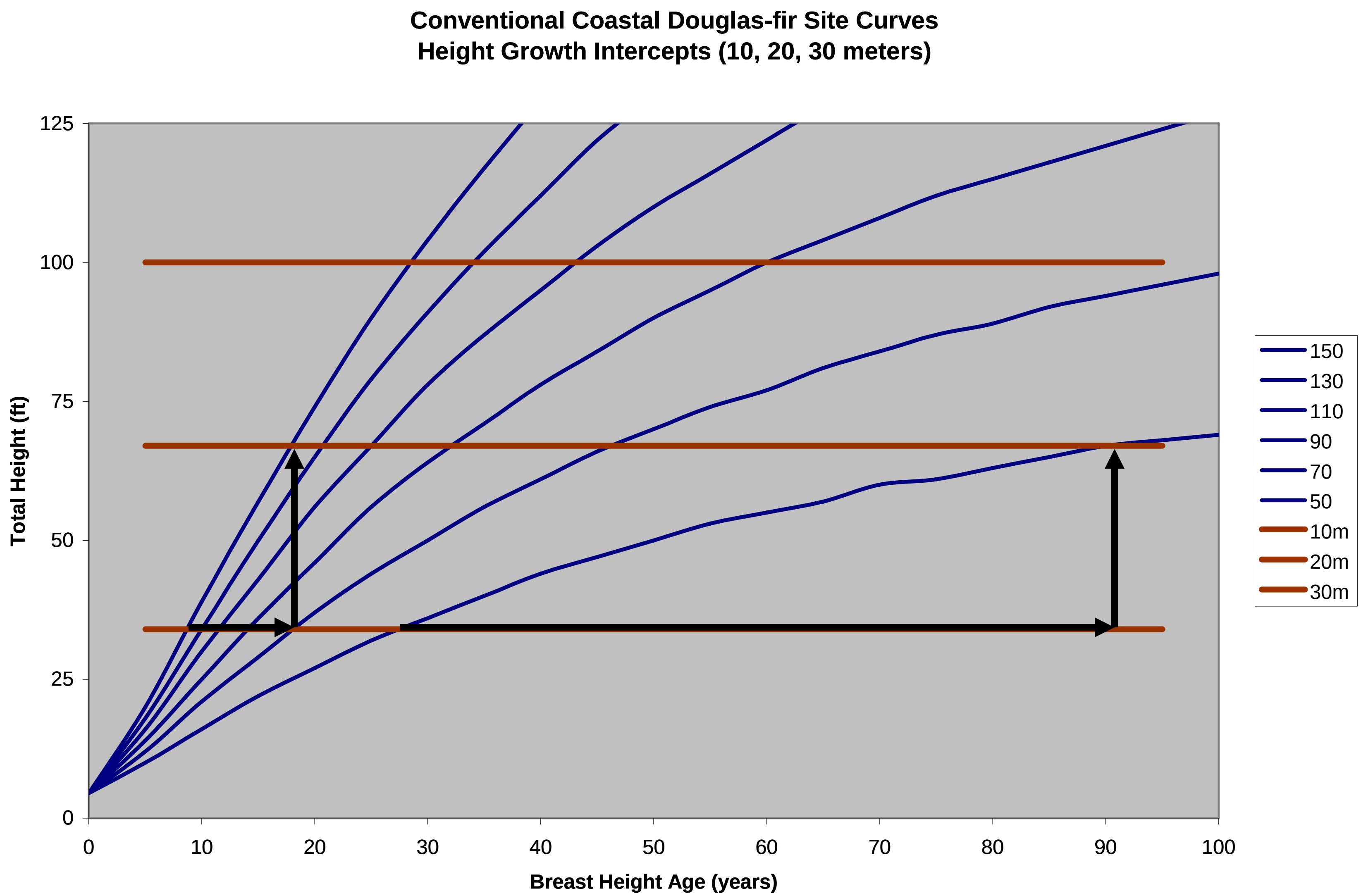
The **problem** is that foresters continue to apply breast height age as the basis for site classification. This is also an application of the two-point principal, but one of the height / age pairs is now 4.5-feet at zero years of age. As previously mentioned, early stand development is highly dependent on early silviculture and competition from other vegetation and animals. These other factors severely impact the determination of site growth capacity when one of the two points remains at such a young age.

This paper describes an approach using Zeide's two-point principal where:

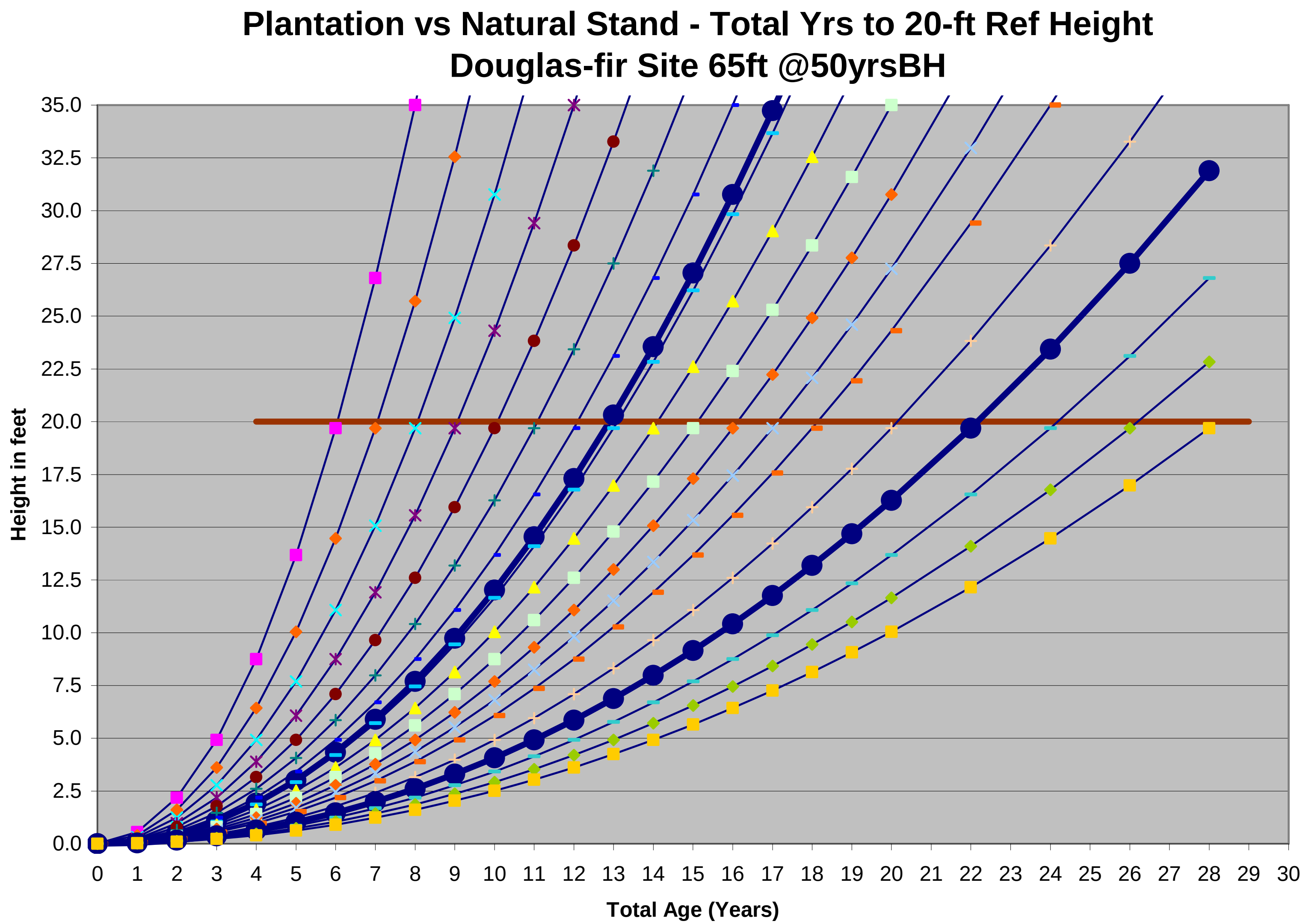
1) The initial point of reference is shifted up the tree from breast height (4.5 feet) to a height of ten meters (32.8 feet). To facilitate field measurements the reference height is identified in this paper as 34-feet which incorporates nominal stump heights and trim allowances for log merchandizing once the sample tree is on the ground.
2) The second point of reference is fixed at twenty meters (67-feet) up the tree. This provides the opportunity to establish an absolute site capacity index with no other information.
3) A third point of reference is fixed at thirty meters (100-feet) up the tree. This provides the opportunity to stratify regional differences in growth curve shapes within a species as we observe site capacity across the range of the species.

The chart on the following page displays the relationship between these three reference heights and the progression of height / age curves by site class for Douglas-fir (Jim King, 1966.  Weyerhaeuser Forestry Paper No. 8).  Notice that each change in site class curve results in different numbers of years to achieve a 10-meter height growth (from 34 to 67 feet).

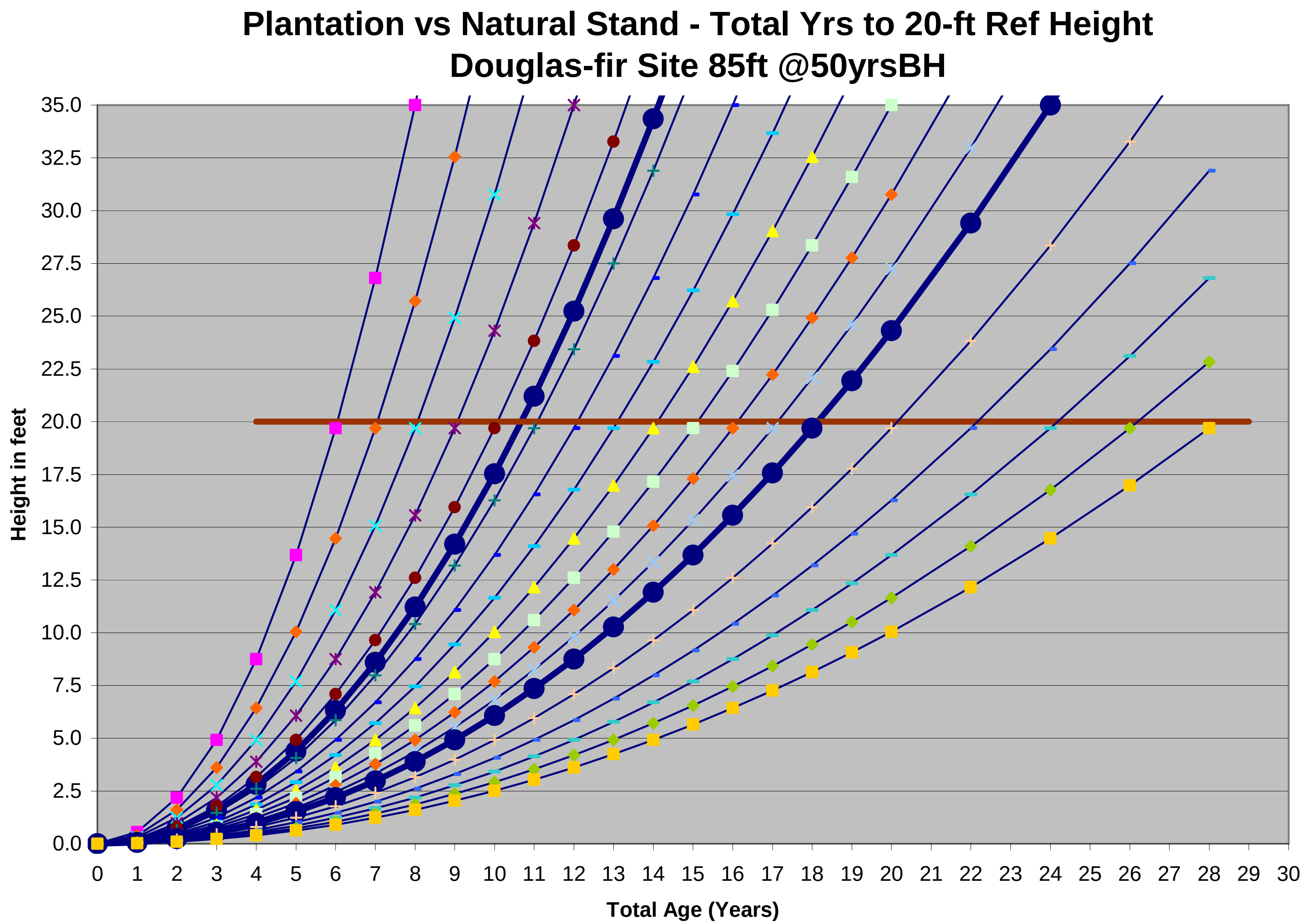
The next four charts display the height / age trend from total age zero to 10-meters (34-feet) based on King's Douglas-fir site classes 65, 85, 105, and 125.  The bold curve to the right of each chart is the Douglas-fir site curve from King's publication.  The bold curve to the left is the result of current research experience in intensively managed plantations.

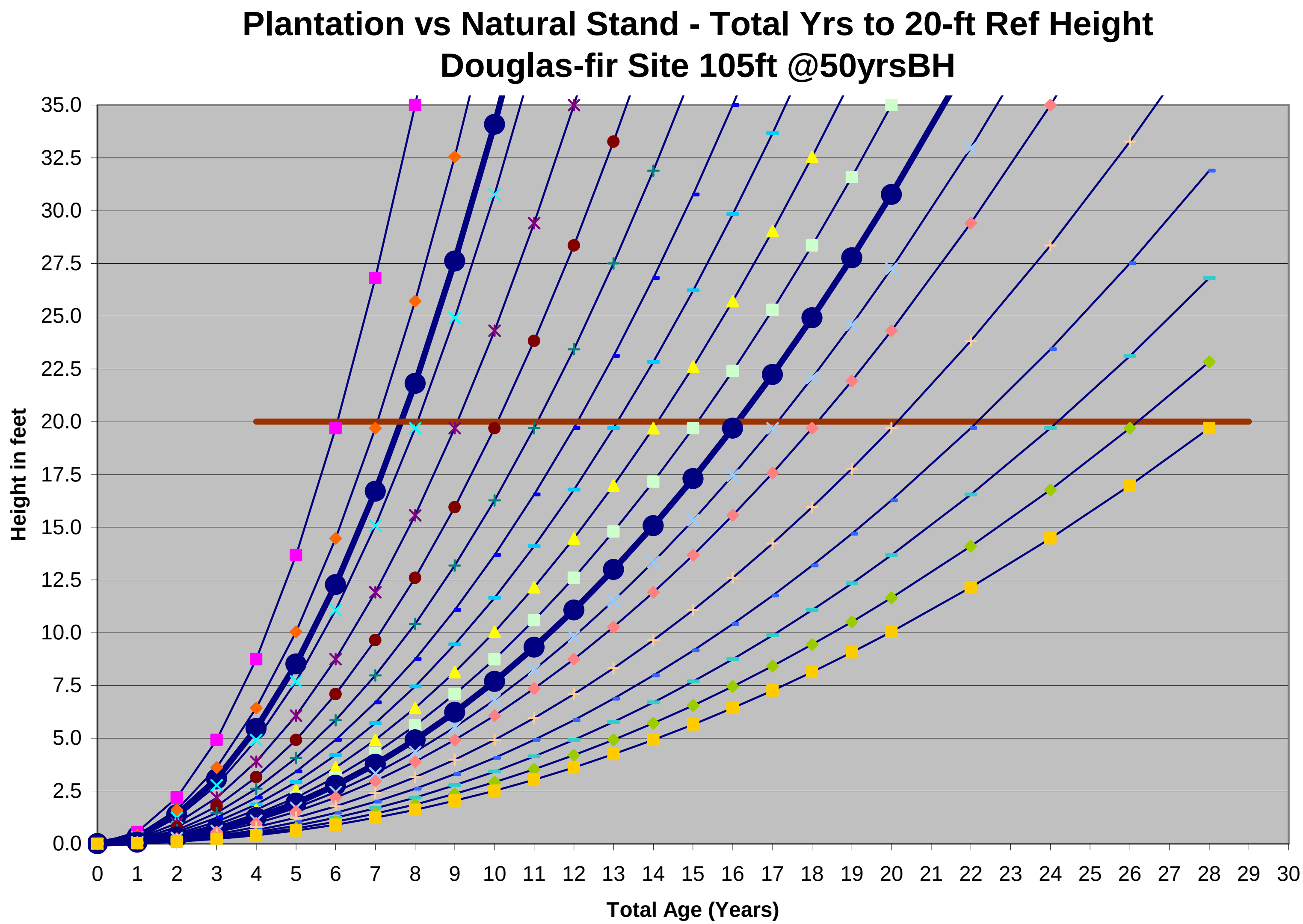


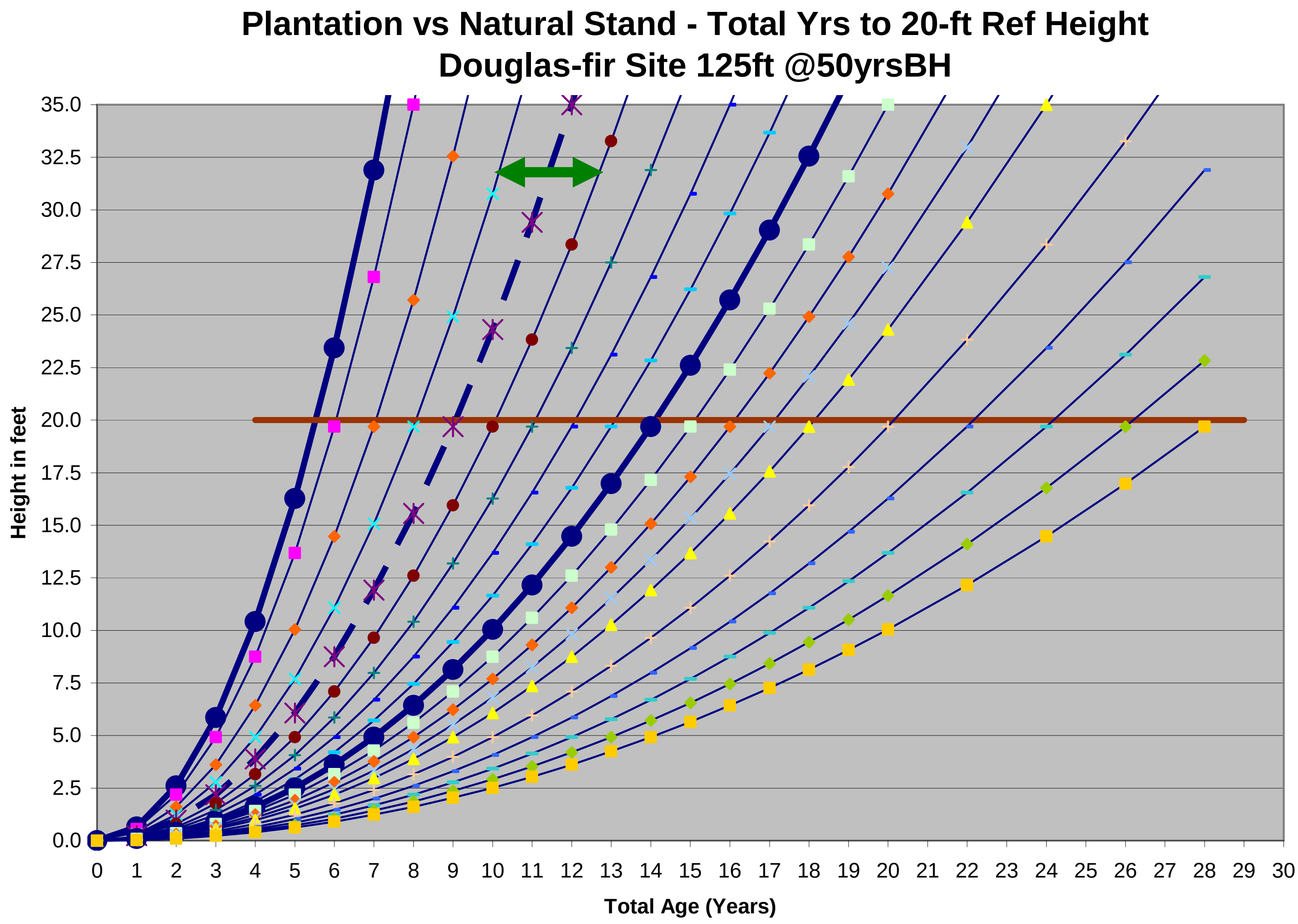
Conventional Coastal Douglas-fir Site Curves
Height Growth Intercepts (10, 20, 30 meters)
Total Height (ft)
125
100
75
50
25
0
0
10
20
30
40
50
60
70
80
90
100
Breast Height Age (years)
150
130
110
90
70
50
10m
20m
30m



Plantation vs Natural Stand - Total Yrs to 20-ft Ref Height
Douglas-fir Site 65ft @50yrsBH
Height in feet
Total Age (Years)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
32.5
35.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Plantation vs Natural Stand - Total Yrs to 20-ft Ref Height
Douglas-fir Site 85ft @50yrsBH
Height in feet
Total Age (Years)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
32.5
35.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Plantation vs Natural Stand - Total Yrs to 20-ft Ref Height
Douglas-fir Site 105ft @50yrsBH
Height in feet
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
32.5
35.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Total Age (Years)



Plantation vs Natural Stand - Total Yrs to 20-ft Ref Height
Douglas-fir Site 125ft @50yrsBH
Height in feet
35.0
32.5
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Total Age (Years)

The chart on the previous page also includes a dashed line which represents the average height growth of over 5,000 trees in an Oregon Coast Range Douglas-fir progeny installation which achieved 19.8 feet of height in nine years. It was established over twenty years ago using then current site preparation, planting stock and brush control methods. Today's operational intensive silviculture and planting stock are exceeding that growth rate.

It is obvious that any yield table or growth model using natural stand site curves to project early stand growth is going to significantly understate the yield capacity of today's managed forests. Foresters continue to attempt to use breast height age as the primary reference point for the determination of site capacity. The 10m Site method sets that reference point aside. It is no longer relevant to determination of site and yield capacity.

**Interpretation of 10m Site Measurements**

Higher site growth potentials can achieve growth from 34 to 67-feet in fewer years than lower sites. For example, in the first chart a site class of 150 can achieve this growth step in eight years while a site class of 50 may require as much as sixty years (bold arrows).

To distinguish the 10m Site Capacity classification from traditional indices (30-160), it is being represented here as the number of meters of height growth that may be attained in one decade (10 years). Simply divide 100 by the number of years observed to grow 10 meters (34-feet) in height. The 10m Site Classification is (10 * 10/Years):

| 10m Site Class | # of Years from 34-feet to 67-feet in Height |
|---|---|
| 12 | 8.3 |
| 11 | 9.1 |
| 10 | 10.0 |
| 9 | 11.1 |
| 8 | 12.5 |
| 7 | 14.3 |
| 6 | 16.7 |
| 5 | 20.0 |
| 4 | 25.0 |
| 3 | 33.3 |

An Appendix, "FBRI 10m Site Class Tables", is provided with this paper which contains these Site Classes as individual pages for each level (3 to 12 meters/decade).

Each page in the Appendix contains seven columns which represent the regional trend in site curve shape for a given site level. If the number of years from 34-feet are recorded for two upper heights (67 and 100-feet), then both the site index level and site index shape may be determined from these sets of tables. Once the site shape is determined for a given site level, it becomes the reference shape for that site level in the Species Library. The procedure on the following page demonstrates these steps using King's Site 120 data.

## FBRI Tree Silviculture, Site and Taper Record

| | Tree #: 101 | | | | Tree #: | | | |
|---|---|---|---|---|---|---|---|---|
| | Species: DF | | | | Species: | | | |
| **Msmt** | **Dob** | **Dbt** | **Height** | **# Rings** | **Dob** | **Dbt** | **Height** | **# Rings** |
| **Top** | | | | | | | | |
| **100-ft** | 0.0 | 0.0 | 99.6 | 0 | | | | |
| **67-ft** | 7.8 | 0.4 | 66.5 | 15 | | | | |
| **34-ft** | 13.2 | 0.8 | 32.3 | 27 | | | | |
| | | | | | | | | |
| **Crn Base** | 9.7 | 0.6 | 56.7 | | | | | |
| **80% Dbh** | 13.0 | 0.8 | 31.2 | | | | | |
| **Breast Ht** | 16.2 | 1.0 | 4.5 | 38 | | | | |
| **Stump Ht** | 17.9 | 1.1 | 1.0 | | | | | |
| **Increment:** | | | | | | | | |
| **34 to 67** | | | 34.2 | 12 | | | | |
| **67 to 100** | | | 33.1 | 15 | | | | |
| **Site Index:** | | | | 8.3 | | | | |
| **Shape Index:** | | | | 80% | | | | |

**Site Class (meters)** = 100 / (Years to Grow from 34 to 67 feet in Height)
**Years** = Number of Annual Rings found at 34-foot Tree Height as an Index to this Site Class
**Shape Class Percentage** = (Years to Grow from 34 to 67 feet) / (Years to Grow from 67 to 100 feet)

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**Example:** Douglas-fir Site Index Curves by Jim King (Weyerhaeuser Forestry Paper No. 8, July 1966, Weyerhaeuser Forestry Research Center, Centralia, Washington)

50-yr Breast Height Site Index 120 (page 46) provides the following age / height pairs:

| BH Age (yrs) | Height (ft) | Description |
|---|---|---|
| 11 | 32.3 | ← Near 34-foot height (10 meters) |
| 12 | 35.4 | |
| 23 | 66.5 | ← Near 67-foot height (30 meters) |
| 24 | 69.1 | |
| 38 | 99.6 | ← Near 100-foot height (30 meters) |
| 39 | 101.5 | |
| 50 | 120.0 | |

Record these age / height pairs in the table at the top of the page to determine the 10m Site Index for this tree profile. FBRI Site index and shape are determined from the increment in years between 10-meter and 20-meter height and between 20 to 30 meters, respectively.

This method works equally well for felled-trees or existing published site index tables.

## Genetic Variation versus Site Capacity

It is also worth noting that the 5,000 trees on the Oregon Coast Range progeny installation demonstrated an average 10m Site Index of 10.8 meters. The range in growth capacity by the slowest to greatest 10-meter height increment above 34-feet in height demonstrated a range of 11 percent in demonstrated growth potential from the worst twenty families to the best twenty families (300-320 trees in each average, Green arrow in the last chart).

Besides separating the early silvicultural effects from the determination of macro-site capacity, the 10m Site Classification provides a robust means of stratifying the growth capacity among families in genetic progeny trials. This method is robust and repeatable.

## Summary Components of the 10m Site Classification Method

- Growth rates from zero to 34-feet of height are primarily driven by *silvicultural effects*.
- Growth rates from 34 to 67-feet of height are primarily driven by *site capacity and genetics*.
- Growth rates from 67 to 100-feet of height are primarily indications of *regional variation within a species* which should be incorporated into a local FBRI_Lib.mdb Species Library for each species of interest.

## Field Collection and Measurements

A field form and Excel spreadsheet are also included with this paper for collecting felled-tree measurements to determine silvicultural effect, site classification and local growth shape. The field form emphasizes measurement points near 34, 67 and 100-feet of height. These measurement points do not need to be precisely at these heights. It also provides suggested input for taper profiles and geographic reference to the sample location. The spreadsheet provides input from either field data or traditional published site index curves.

Field samples within each sampled stand should be based on a minimum of a three-tree sample of the same species which are located near enough to one another to minimize the risk of entering a new physical site condition. Three or more trees are necessary to control variation in site estimation due to genetic variation and micro-site fluctuations. If the means of three trees is more than five (5) feet different than the mean of two trees, then additional trees should be sampled. Sampling will be completed when the rolling average does not change by more than five (5) feet.

At each field sample location, determinations should be made for each of several parameters. Variables include total soil rooting depth, aspect, slope, elevation, position on slope, soil texture and soil parent material. Soil rooting depths should be recorded to a maximum of sixty inches. Aspect and slope should be the general land topography at the sample location. Solar radiation will be determined from these measurements of slope and aspect. Elevation should be recorded to the nearest one hundred feet. The GPS location should also be obtained to assist in Digital Elevation Model subsequent analyses.

Care should be taken to systematically traverse the range of the ownership (tree farm, forest, reservation, watershed) in terms of historic site productivity, elevation, solar radiation (slope / aspect), precipitation and soil type. Each major independent parameter should be incorporated into the sampling design at the outset.

Species favored for measurement as site trees should be a predominant species that occurs across the entire ownership. For example, this is typically Douglas-fir in the Western United States. The analyses relating soil and climate parameters to site index may be most successful if the site measurements are all obtained from a single species. However, no single species may occur at every sample location, making it necessary to determine site index differences among species in the same stand. It is recognized that relative growth rates among species may not be consistent over the entire ownership. However, differences by species at sampled locations provides a means to estimate the site index of the primary species even though it may not be available for sampling at each location. By using these average ratios by species, all site measurements may be converted to the predominant species values.

The next phase of the project is to develop relationships between observed site index values by location and the associated edaphic, climatic and topographic parameters. The approach is iterative, beginning with a stepwise regression search for the independent variable which explains the greatest amount of variation in site index level.

The second step in the iteration process is to compute the differences between observed site index and site index predicted by the best single variable equation. The differences may then be plotted over the predicted site index for each independent variable in the equation and for each candidate additional independent variable. If the differences with respect to the newly added independent variable are randomly distributed, then the form of the equation representing that variable is adequate to describe the effect of that variable on site index. If the differences are skewed, then some additional transformation of the independent variable will be needed. The importance of this skewed (non-linear) relationship is then tested by adding a squared term for the independent variable in question to the regression fitting procedure. If the F-statistic is significant for the independent variable squared, then various forms of curvilinear transformations on the independent variable are conducted.

The third step of the iterative process is to evaluate the change in significance of independent variables included in the equation prior to making transformations on the most recently added variable. Due to limitations in sample size and selection, some of the independent variables may be correlated. This correlation may cause some relationships between independent variables and site index to strengthen and others to weaken as new variables are added to the equation. Once these concerns are satisfied, the procedure is to return to the first step of the iterative process to look for the next independent variable not already included in the equation.

The site index equation developed in this analysis should provide a productivity classification for all stands based on easily observed soil, climatic and topographic parameters. This classification may then be reduced to a GIS productivity classification layer for the forest inventory as a permanent site productivity classification of all lands.

**Literature Cited**

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Zeide, Boris. 1978. Standardization of Growth Curves. Journal of Forestry 76(5):289-292.