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By

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(back of cover page)

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By
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It has always been appealing to attempt to estimate site index by observing the height growth rate in young trees at early ages (Bull, 1931). Various methods have been proposed with varying starting heights and numbers of years to observe (Wakeley, 1954).

With the development of the 10m Site Index classification methodology (Arney, 2010) there is now the opportunity to take very useful field methods and separate the best use of their application between a) macro-site classification of natural forest growth capacity or b) micro-site effects of silvicultural treatments.

There is a very definite and specific need to be able to characterize improvements in early stand growth, due to silvicultural investment, in a quantitative and repeatable way. This characterization is most useful if conducted as early after stand establishment as may be measureable, repeatable and defensible.

The timing of this characterization of silvicultural gain is constrained by two delaying factors:

1) sufficient time must elapse to realize any gains from the silvicultural investment (planting stock, container size, site preparation, brush control, pest control, nutrient management, etc.); and,
2) sufficient dimensional differences must occur to observe significant differences from baseline expectations within the practical limitation of field measurement devices and methods.

If either of these two delaying factors is not met, then it is not possible to quantify the investment in silvicultural treatments. As with most forestry investments, the justification of choice of planting stock, container size, site preparation method, herbicides and pesticides must be provided as early as is feasibly possible. Traditional forestry research projects develop tests of significant responses within controlled environments; but they often do not provide the means to evaluate similar treatments when applied on an operational basis.

The objective of this article is to present and justify a methodology for assessing silvicultural response to various kinds and intensities of treatments in the early development of a forest stand. The primary factors for measuring silvicultural response are the elapsed time and field instrumentation limitations mentioned in the introductory comments.

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Height-Intercept Methods

One approach aimed at quantifying growth dynamics in plantations is the height-intercept approach (Zeide, 1978). This technique involves measurement of height and age along various points of the stem. Bull (1931) tested various height points and the number of years (ring count difference) between them. He reported erratic results with the points he chose all of which were below 15 feet. Some years later Wakeley (1954) proposed a more stable system call the "five- year height-intercept" by moving their reference point further up the stem. The length of the first five whorls above BH were measured and used to rank site potential. They found it useful to avoid the height growth from zero to breast height. Ferree et al. (1958) states, "Confining growth measurements to the portion of the stem above BH greatly reduces the effect of irregularities during the establishment period" and "It is evident that inclusion of height age data from below 4 ½ feet would interject a large and unrelated variation into site index calculations". This method seemed to work well for ranking the success of plantations, although as Wakeley (1958) points out the five-year intercept method was generally but not always highly correlated with total height. Day et al. (1960) demonstrates that with careful selection of regional site curves, the five-year intercept method can be strongly correlated to total height/age site index curves. However, for practical utilization, Ferree (1958) advises that the five-year height-intercept method not be used for extrapolation to ages older than about 20 years.

The variation between site index estimated by a five-year intercept method versus a total height/age method, could be due to continued volatility in height growth increment due to early silviculture (as Wilde 1964 speculates) above the breast height point. This was not completely accepted, since other authors contend that dominant and co-dominant trees have reached their maximum height potential by 4.5 feet, (Oliver 1972).

Wakeley (1958) found the direct measure of site using a height-intercept method useful because it does not require curves built on averaged data and facilitates comparisons between different plantations and different species. It follows that if we move the reference point further up the tree we should be able to escape much of the variation in height growth due to the intensity of early silviculture and thus reduce bias in site potential estimates. A direct measure utilizing growth intercept may be more closely related to environmental variables than traditional site index (Van Laar and Akca, 2007).

Because early silviculture (or lack thereof) affects height growth, any height-intercept method below approximately 10 meters (34-feet) will result in a biased estimate of site.

The essence of macro-site is the height growth development beyond the influence of early silviculture. Definition of this growth capacity has been the goal of every author of a published site index curve and table, such as Haig (1932), Meyer (1938), King(1966) and Monserud (1985). The 10m Site Index method (Arney, 2010) standardizes on height growth from 10 to 20 meters (34 to 67 feet) in total height. This growth rate may be observed directly on felled-trees or by interpolation from published site index height/age curves. It separates the early silvicultural effects (micro-site) from macro-site effects.

The 6m Height Intercept Method

In the discussion of determining natural site index capacity, it is appropriate and warranted to move above breast height to depart from the influences of tree establishment delays and competition from non-tree vegetation and animal browsing. For these reasons 10m Site Index methods do not use any height/age measurements below 10 meters (34 feet) of height. While most silvicultural effects may have become insignificant at much shorter height intercepts, maintaining this threshold of 10 meters keeps the separation of early silviculture and macro-site in clear distinction for field measurement. If the trees in a stand are observed to grow ten percent faster at heights of 10 meters or more, then it is likely due to a higher macro-site capacity. If the trees in a stand are observed to grow ten percent faster at heights of 1 to 5 meters (3 to 12 feet), then it is likely due to a different silvicultural treatment history.

The height growth rates below breast height become important when the objective is quantification of silvicultural treatment rather than macro-site classification. Therefore, it appears evident that the beginning height intercept threshold should be a height of zero.

The height intercept methodology calls for a beginning height and a fixed number of years to achieve some height capacity. The attained height after the specified number of years is the index of interest. An alternative approach is to maintain the beginning height threshold but identify an ending target height reference. The number of years to achieve that target height becomes the index of interest.

The beginning threshold height and target height pair has much appeal. Using fixed numbers of years has limitations for field applications when a wide range of natural site capacity may be considered. Five-year intervals have been popular in the past to assess rates of growth. However, on low sites or stands with intense competition from other factors, a five-year intercept may only involve 3 to 6 feet of height growth. Typical stand conditions in the West demonstrate that slight micro-site effects may significantly change the outcome of a five-year intercept sample. Thus, derivation of reliable ranking of silvicultural treatment results becomes prohibitive. A clear and measureable difference in height achieved on the treated stand is required.

A successful measurement method is reliant on field instrumentation matched to the growth interval defined for ranking silvicultural treatment effects. For example, a typical threshold for silvicultural investment decisions is a height gain of at least 10 percent over the baseline stand. Additionally, in practice, our field measurement methods are typically accurate to about the nearest one foot. There are height pole methods more precise on an individual tree basis for tagged tree research trials, but operational field surveys typically on use temporary sample plots and measurements. Therefore, it is warranted, prudent and practical to assume at least a two-foot difference between treated stand and baseline stand measurements to confirm a significant difference in practice.

Combining these criteria for a height-intercept methodology to assess silvicultural treatment effects results in the following recommendations:

1) set the threshold height for beginning measurements at a height of zero;
2) use the number of years to achieve a target height as the index for ranking;
3) assume at least a 10 percent difference from baseline to be significant; and,
4) require at least a 2-foot difference from baseline growth to be significant.

To observe at least a 2-foot difference for a minimum of 10 percent of height growth requires a total height of twenty feet. Therefore, the recommended index for assessment of silvicultural treatment success becomes the number of years to achieve twenty feet of height from time of establishment of the stand. Figure 1 provides a table of the number of years observed to achieve a total height of twenty feet within each site index level.

The "% Regen" column to the left becomes the index of silvicultural growth response. It is the ratio of macro-site growth rate divided by the micro-site growth rate as observed. For example, a traditional 50-year site 90 will grow twenty feet in 10.2 years at heights between 34 and 70-feet in height (Arney, 2010). If newly regenerated trees in a stand are observed to achieve 20-feet in 14-years, then the % Regen response = Site Yrs/14, which is 73% of site capacity as these trees establish themselves. (i.e., 10.2 / 14 = 73%)

The % Regen silvicultural response rate is then applied directly in the FPS Growth Model (Arney, 2015) to localize early growth as observed from this regeneration survey observation. It is readily apparent that harvest ages and cash flows are significantly impacted depending on the observations of these early silvicultural growth responses.

Figure 1. Classification of Silvicultural Response by Site Class – The CASH Card.

FPS - Silvicultural Treatment Response Classification

Site Class	CASH Card (Correct Age, Site, Height)												
25yr	35	40	45	50	55	60	65	70	75	80	85	90	95
50yr	40	50	60	70	80	90	100	110	120	130	140	150	160
10m	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**	**11.0**	**12.0**	**13.0**
%Regen	*Number of Years to Achive 20-ft Height (6m)*												
40%	152.4	76.2	**50.8**	38.1	30.5	**25.4**	21.8	19.1	**16.9**	15.2	13.9	**12.7**	11.7
52%	117.2	58.6	**39.1**	29.3	23.4	**19.5**	16.7	14.7	**13.0**	11.7	10.7	**9.8**	9.0
64%	95.3	47.6	**31.8**	23.8	19.1	**15.9**	13.6	11.9	**10.6**	9.5	8.7	**7.9**	7.3
76%	80.2	40.1	**26.7**	20.1	16.0	**13.4**	11.5	10.0	**8.9**	8.0	7.3	**6.7**	6.2
88%	69.3	34.6	**23.1**	17.3	13.9	**11.5**	9.9	8.7	**7.7**	6.9	6.3	**5.8**	5.3
100%	61.0	30.5	**20.3**	15.2	12.2	**10.2**	8.7	7.6	**6.8**	6.1	5.5	**5.1**	4.7
112%	54.4	27.2	**18.1**	13.6	10.9	**9.1**	7.8	6.8	**6.0**	5.4	4.9	**4.5**	4.2
124%	49.2	24.6	**16.4**	12.3	9.8	**8.2**	7.0	6.1	**5.5**	4.9	4.5	**4.1**	3.8
136%	44.8	22.4	**14.9**	11.2	9.0	**7.5**	6.4	5.6	**5.0**	4.5	4.1	**3.7**	3.4
148%	41.2	20.6	**13.7**	10.3	8.2	**6.9**	5.9	5.1	**4.6**	4.1	3.7	**3.4**	3.2

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This figure is identified as a "CASH" card because it identifies the Correct Age, Site and Height (CASH) to characterize a given level of silvicultural response.

The CASH card may be taken to the field and used consistently for classification of all natural and planted stand development. All plantations should be ranked using this method. Treatments and planting stock differences are easily ranked.

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