CHAPTER 5

CHANGE MONITORING WITH PERMANENT SAMPLE PLOTS

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5.1 CONCEPTS AND NOTATIONS

There is nothing else permanent in nature but change. Everything is moving, as the Greek philosopher Herakleitos stated some 2500 years ago. In even-age forestry, forest stands develop from open areas and young plantations to mature stages, and in all situations individual trees either grow annually, are felled or face a natural death through the struggle for existence, storms or other sources of damage. Changes in forest growing stock can be measured and to some extent attributed to human activities and changes in general growth factors: temperature, moisture, nutrients and light conditions. The estimation of such changes has become an increasingly important objective in forest inventories and in other contexts. Duncan and Kalton (1987), in their comparison of alternative survey designs in relation to various inventory objectives, found that remeasurement of permanent sample units is the best and often the only way to estimate components of change over time and aggregate data for individuals over time.

When forest inventories and monitoring surveys are based on the use of permanent sample plots the definition of the necessary terms should be connected with the performing of periodic measurements. Discussions of the respective terminology and methodology have been presented by many authors, e.g., Chapman and Meyer (1949), Beers (1962), Ware and Cunia (1962), Nyyssönen (1967), Cunia and Chevrou (1969), Newton et al. (1974), Martin (1982), van Deusen (1989), Päivinen and Yli-Kojola (1989), Gregoire (1993) and Eriksson (1995). We will concern ourselves here only with changes in tree and growing stock dimensions and quantities. Changes in stand variables such as site indices or environmental properties are not included.

The sampling unit can be a plot of either fixed or variable size, the most common fixed-sized plots being circular ones and the most common variable-sized plots concentric circular plots or Bitterlich relascope plots (or units of horizontal...
point sampling). Concentric circular plots are ones in which trees belonging to the class of “small trees” are included or tallied on the basis of a shorter radius than “large trees”. The number of classes can also be greater than this.

Regardless of the type and size of the plot, the plot-based measurements are transformed or expanded for an area of standard size \( A_{\text{std}} \), e.g. 10,000 m\(^2\) or one hectare, using the expansion factor

\[
e_i = \frac{A_{\text{std}}}{a_i}, \tag{5.1}
\]

where \( a_i \) is the plot size corresponding to the size of the tree \( i \).

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**Example 5.1**

- \( A_{\text{std}} = 10,000 \) m\(^2\) (one hectare)
- \( \text{dbh} = 23.6 \) cm

The basal area factor is 1 (one tree on the plot corresponds to 1 m\(^2\)/ha or the maximum plot radius for the tree is 50 dbh).

The maximum radius for tree \( i \) to be included in the plot = 11.8 m

Then

\[
a_i = 3.1416 \cdot (11.8 \text{ m})^2 = 437.43 \text{ m}^2,
\]

and

The tree expansion factor 22.86 means that one tree tallied on the plot

\[
e_i = \frac{10000 \text{ m}^2}{437.43 \text{ m}^2} = 22.86
\]

corresponds to 22.86 trees/ha.

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The tree expansion factor \( e_i \) is constant for every tree and measuring time in the case of fixed-sized plots, but with variable-sized plots it may vary depending on the size of the tree. If relascope plots are used, for example, the tree expansion factor at the time of the later measurements will be smaller than it was at the beginning, on the assumption that the trees will have grown.

The equation for estimating plot values \( Y_{jdt} \) for plot \( j \), domain \( d \) and time \( t \) is calculated by multiplying the tree values by the per-standard-area expansion factor.