POINT-INTERCEPT SAMPLING IN REVEGETATION STUDIES: MAXIMIZING OBJECTIVITY AND REPEATABILITY[1]

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Abstract.--Ocular estimation in plots, line intercept, and point-intercept are all common methods for determination of plant cover percent. By their nature, each has strengths and weaknesses which should be matched to applications in which the strengths are important and the weaknesses are not. Ocular estimation in quadrats produces information on relative abundance of most species present, but absolute cover values may be variable between observers due to complexity of mental integration involved. Point-intercept sampling, in the opposite manner produces absolute cover values that can be expected to be the most repeatable between observers, but point data emphasize the major species. Ocular estimation in plots is best suited to descriptive plant ecological purposes where complete information on species is important but confidence in absolute cover values and repeatability is not. Point-intercept methods are best suited to applications such as mine permit baselines and testing for revegetation success, where maximum confidence in absolute cover and repeatability is paramount and information on the full range of individual species' cover values is not.

INTRODUCTION

With the passage of the Federal Surface Mining Control and Reclamation Act of 1979 (SMCRA), the permanent federal regulatory program under that act (30 CFR 700,800), and state programs pursuant to the provisions of the federal act and regulations, the widespread use of quantitative performance standards to judge revegetation success quickly emerged. Quantitative data were to be collected from revegetated areas, and compared to data collected from reference areas, climatically corrected baseline data (usually using control areas), or technical standards developed by historic record of the site or other means. The statistical attention given to adequacy of sample size and comparison of means from revegetated areas to standards has necessitated the evaluation of the suitability of the data collection techniques to provide sufficiently precise measurements and accurate estimates. Of the basic vegetation parameters measured in the field for use in revegetation success determinations, that is, plant cover, annual biomass production, and woody plant stem density, cover is perhaps the parameter for which data collection techniques are most variable.

Techniques used to collect cover data can be recognized in three categories: ocular estimation in plots, line intercept, and point sampling. All had been used widely in plant ecological research prior to their use in mine permit studies. The methods have been compared previously to determine their relative accuracy and efficiency (Goodall 1953, Whitman and Siggeirsson 1954, Decker Coal Company 1981, Bridger Coal Company 1984). However, the examination of the various methods in light of the purposes to which resulting data are applied has not been undertaken and is the subject of this brief contribution.

REASONS FOR COLLECTING COVER DATA

Historically, cover data have been collected primarily for use in plant ecological descriptions or range condition assessments. In studies to describe plant ecological features, it is typical to use cover data to document the relative

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abundance of the various plants comprising a plant community. In certain traditions of plant ecology, such as European phytosociology, the presence of minor species is of great importance in interpretation of vegetational classification. There is, on the other hand, typically relatively little importance in knowing the absolutely accurate percentage cover. In fact, often cover data for plants from different strata (synusia) are included in the same table causing total cover reported to exceed 100 percent, which is of no particular concern. In range condition determinations, it is again typically the relative proportion of the species that is of interest, not the absolute cover value.

By contrast, cover data collected for surface mining revegetation are or will be primarily used to determine total percent plant cover. Confidence in the accuracy of the estimate of total percent cover will be of importance because of the eventual statistical comparison of revegetated area cover to a standard such as reference area cover, and the dependency of such comparisons on the release of the financial responsibility of the coal companies embodied in performance bonds. The relative contribution of particular plant species to total cover will be of importance in determination of satisfactory diversity but, in most cases, it will be the major species that will be of interest. Minor species in the range of one percent cover and less do not enter into consideration, in general. Cover, for purposes of mine permit/revegetation applications, has typically been taken to mean the cover of the uppermost stratum; that is, the first vegetation, if any, encountered in a vertical projection downward. Cover in underlying strata is of ecological importance, but is not usually considered in the statistical evaluation of revegetation success.

HOW COVER METHODS WORK AND WHAT THEY SHOW

Ocular Estimation in Plots

Ocular estimation in plots involves observation of vegetation from a vertical prespective within the bounds of a plot, often rectangular but sometimes circular. Rectangular plots often have means of referencing various percentages of the area enclosed, either in the form of marked divisions on the edge of the plot or by means of a wire grid stretched across the plot. The data on percent cover for each species come from estimates that integrate the percentage of the plot area occupied by the leaves, stems, and reproductive parts of the plants. Since these parts are of extremely variable and complex shape, the estimate of percent cover involves a mental integration of a large number of often small areas into one area whose cover is, in turn, mentally matched to a known area prescribed by the reference marks or grid of the plot. This is typically done for each species occurring in the plot, as well as total cover.

The described technique estimates the actual cumulative total of leaf cover for a species, requiring account for spaces between leaves and stems in the canopy of individual plants. The figure arrived at by this technique is known as foliar cover. Rather than attempt to account for spaces between leaves and stems in canopies of individual plants, it is a common technique to mentally circumscribe individual plants with close-fitting polygons. It is then not as difficult to mentally fit these polygons together to arrive at a total cover for the species; the figure known in this case as canopy cover. How "tight" the fit of the polygon is around a particular plant is, of course, another observer-specific variable.

In both methods, there results a cover value for each and every species present, even those minutely so. Thus, in a cover sample based on ocular estimation in plots, data on species over the entire range of abundance result. Of course whether the entire or nearly entire suite of species present in a stand is included in the data depends on the minimal area for the particular stand (see Daubenmire 1968). The mental integrations involved in ocular estimation render the results inherently variable between observers, although it is common for experienced estimators to develop remarkable consistency within themselves.

Prerequisite to the use of the ocular estimation method and the line-intercept method (below) is achievement of vertical perspective, that is, observation of subject vegetation from a height sufficient to allow the line of view to be vertical, or very nearly so, throughout the plot. The constraint of typical human height of about 1.5 m in turn constrains the size of plots to about 1 m^2 in applications where there is any importance at all to accurate cover determinations. Larger plots introduce a substantial parallax distortion from a vantage point of 1.5 m. Because of the need to achieve a vertical perspective, proper assessment of vegetation taller than low shrubs is logistically almost impossible.

Line-Intercept

In the line-intercept method of cover estimation, the two dimensions of ocular estimation in plots are reduced to one dimension. The method is accomplished by stretching a tape across the vegetation and measuring the length along the tape occupied by the foliage (or polygon-circumscribed canopy) of the plants in vertical projection. Line-intercept estimation requires less mental manipulation than ocular estimation. It is rarely used to produce foliar cover estimates due to the tedious nature of projecting and measuring interception of individual leaves.

Since the sampled "area" is only a line in this method, it is intuitively clear that the probability of encountering the scattered, less common species is smaller than in two-dimensional samples.

Line-intercept data are properly collected from a vertical perspective, as are data from plots. Projection of the vertical boundaries of tall plant canopy onto the line can be accomplished somewhat more objectively than similar projection onto plots.

Point-Intercept

In this method, the reduction in dimensions takes the final step to being dimensionless. Cover is determined by the percent of rigidly located, usually vertically projected points that encounter vegetation. Points are often grouped in tens and are projected as the sharpened tips of moveable rods held vertically in frames known as point frames. These frames are very commonly one meter in length, but may be smaller in applications on very low vegetation. Points may also be much more widely spaced, such as points spaced at meter intervals along a 50-m transect. This method has come to be known as the point-transect method.

Mental decisions are meant to be minimized in this method since data recorded are "hits" versus "non-hits". Since it is the goal of this method to minimize subjectivity, the decision of "hit" versus "no hit" must be as clear-cut as possible. Thus, the point whether the tip of a rod or optically projected, must be as nearly "dimensionless" as possible to avoid the chance of partial hits. Likewise, the point-projection must be rigid to avoid decisions about the proper position of moving points. Point-frames must be stiff and sturdy and pins stiff, straight, and sharply pointed. Optical devices for projecting points must use fine cross-hairs and be very securely attached to a heavy, adjustable tripod.

Both these requirements are fairly commonly violated in point-intercept sampling and seriously compromise the method's excellent objectivity and repeatability between observers. In some vegetation and weather conditions, leaf and stem movement due to winds may cause difficulty in point intercept sampling. However, the author has found that the main problem under these conditions is extra time per point necessary to observe the subject plant "at rest" between gusts.

Because observations are limited to a "dimensionless" plot (i.e., a point), the probabilities of a particular species in the vegetation being encountered by a point is very strictly a function of its abundance. Since the difference in cover between the most common and even moderately uncommon species is estimated typically to be at least three orders of magnitude (i.e., 1000:1), it is clear that a very large number of points would be necessary to expect to encounter all species present.

In point intercept sampling, hits on the uppermost stratum of vegetation ("first hits") are tallied separately from further hits on vegetation along that projection before the ground is hit. The cover value used in vegetation success applications is appropriately "first hit" cover. Use of other hit data in conjunction with first hit data provides the best relative cover information and should be used for any diversity calculations undertaken with the data. Similarly, it should be noted that over the history of development of the point-intercept method, angles of projection other than 90° (i.e., vertical) have been used to increase the number of hits and thus show the presence of a larger portion of total species present in the vegetation. Non-vertical projections have also been used for determining leaf area index. For revegetation success analysis, however, vertical projection is the simplest method to implement and interpret.

MATCHING DATA NEEDS WITH METHODS

Descriptive Plant Ecology

As mentioned above, cover data offer a very useful basis for development of vegetation descriptions, in that they show the relative abundance of species and provide a basic organization for the discussion. For interpretive purposes, especially vegetation classification, the information often needs to include information on all plant species present, from the most abundant to the least abundant. For this purpose, it is clear that ocular estimation in plots is the preferred method in conjunction with a consideration of minimal area as suggested by a tool such as a species-area curve (Daubenmire 1968). The possibility that the absolute cover figures, by virtue of highly demanding mental integration, may not be particularly repeatable by different observers is in no way a liability in descriptive plant ecological situations.

Mine Permit Baselines and Testing of Revegetation Success

Pursuant to state and federal coal surface mining regulations, the percent vegetation cover of revegetated lands in comparison to a standard is part of the culmination and final examination of a laborious and expensive process of overburden replacement, grading, topsoiling, seeding/planting, and husbandry. With the cost of these activities often totaling thousands of dollars per acre, the total dollar amount at risk, in the form of a bond, is very substantial. The probability of erroneous determination of failure to achieve the necessary cover must be kept to a minimum. Likewise, from the regulatory point of view, the probability of eroneous determination of success must also minimized. Thus, it is appropriate that cover be measured by the most objective and repeatable method available. This is especially important when realizing that the life of mines may be thirty years and more, the probability of the same personnel conducting the revegetation success tests that conducted the baseline work is small. When reference areas are used, this time variable is eliminated because the standard resides in the reference area for measurement at the time of testing. However, with control areas, historic record, or unadjusted baseline data methods, the data from sometime previous are the standard, with or without adjustment for climatic variation.

With the importance of objectivity and repeatability foremost, the method of choice is point intercept sampling. Because no mental cover integration is involved, it is inherently a more objective and repeatable method. The relative inability of point intercept cover sampling to demonstrate the abundance of minor species in no way detracts from its use for mine revegetation purposes since performance standards to date that address particular species deal with the most abundant.

SAMPLING OF WOODY OVERSTORY

Determination of cover of a woody overstory has been subject to relatively little scrutiny because it has primarily been done in descriptive studies. For the somewhat few coal mines where woody overstory is present as tall shrubs or trees, the accurate determination of cover is important (except in Colorado where cover standards address herbaceous species only). When determining cover by ocular estimation in plots, it is important to do this from a vertical, distant vantage point to minimize parallax distortion. For herbaceous or low shrub vegetation, no more than one or two feet tall, the viewpoint of a standing person suffices. For tall shrubs and trees, the necessary vantage point obviously cannot conveniently be achieved. Cover determination by point intercept is not saddled by the parallax problem and, when used with a tool to project a point vertically up or down, provides the most equitable treatment of all vegetation strata that is available.

SUMMARY

The strengths and weaknesses of the various methods of cover estimation for use in descriptive plant ecology have been previously discussed (see Daubenmire 1968, Mueller-Dombois and Ellenberg 1974). The needs of mine revegetation success evaluation should be recognized as distinct from those of descriptive ecology. The relative inability of point intercept samples of reasonable size to yield information on species across the full range of species abundance is a liability in descriptive ecological applications but is inconsequential in revegetation applications. The advantage of repeatability and potentially greater accuracy inherent in point intercept cover sampling is inconsequential in descriptive ecology but very important in mine area baseline development and testing for revegetation success. The line intercept method falls in-between the other two methods, with neither the full liabilities or advantages in either application.

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