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A SITE CLASSIFICATION FOR THE MIXED-CONIFER SELECTION FORESTS OF THE SIERRA NEVADA

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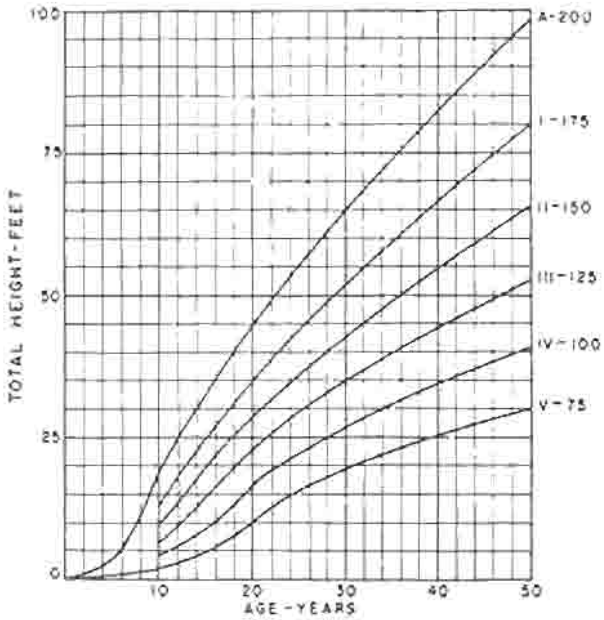

FIG I

Res. Note No 28

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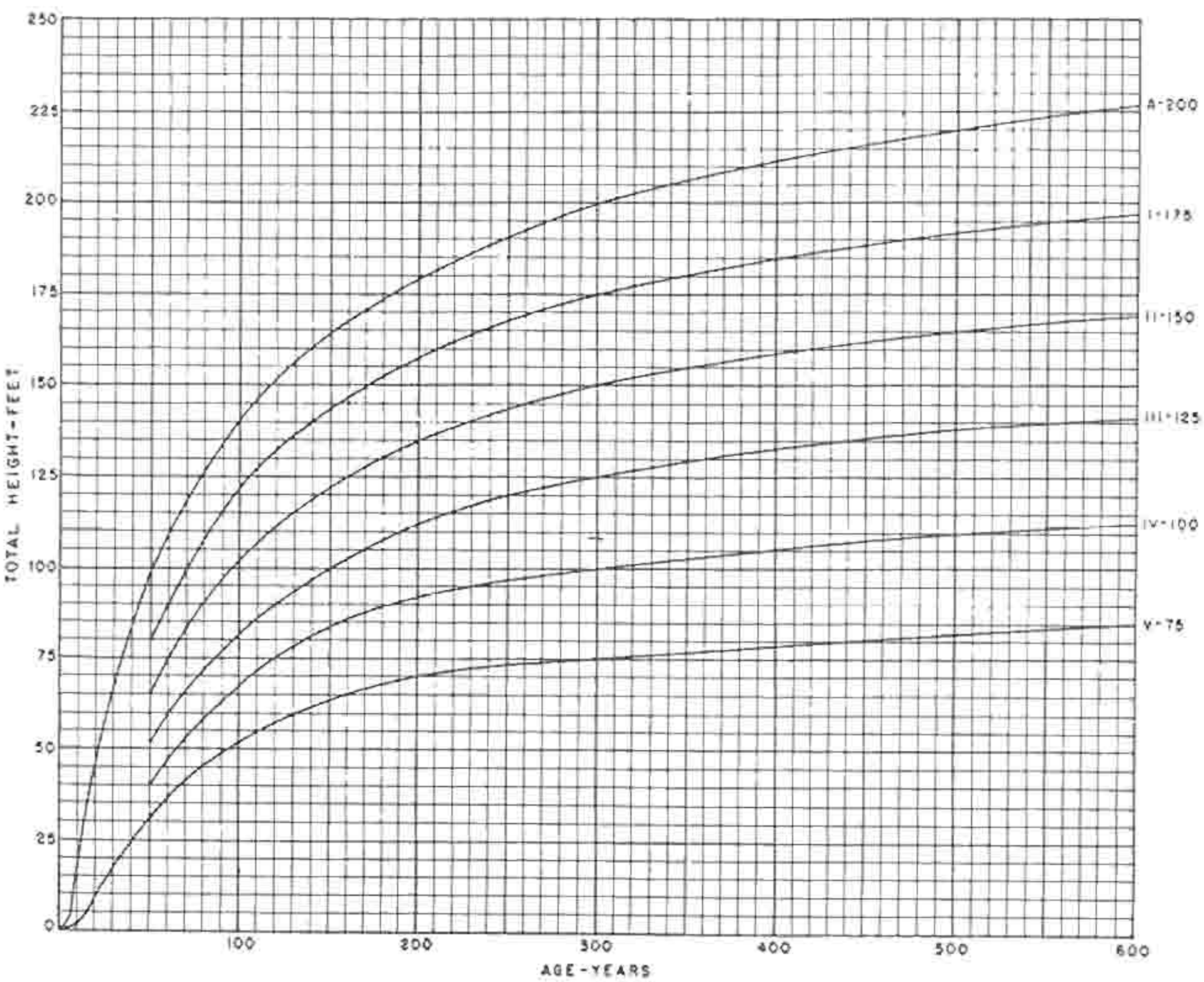

A SITE CLASSIFICATION FOR THE MIXED-CONIFER SELECTION FORESTS OF THE SIERRA NEVADA

INTRODUCTION

Purpose

The site-class curves presented here as figure 1 for the irregular pine-fir forests of California were first prepared in connection with a yield-predicting procedure (1) 1/ developed in 1933. The original curves were designed principally for administrative use of the Forest Service in Region 5. Since they have now come to be accepted by other agencies and for general purposes, this research note has been prepared to make the curves more readily available and to describe their peculiar features sufficiently to enable correct application. It is hoped that this action may contribute to the establishment of a single criterion of site for the region as nearly as possible like that most commonly used in volume surveys, growth forecasting, and other forestry work.

Basis

The height-age relationship here used as a basis for site classification, although widely accepted, is subject to numerous variations in practice. Adoption of standard methods of classifying forest sites was recommended in 1923 by a committee of the Society of American Foresters (2) under the chairmanship of W. N. Sparhawk, but this admonition has been rather generally ignored. Methods will probably never become widely standardized. Uniformity between regions having species in common, though much to be desired, appears to be impracticable. Within this region, where interdependent volume, taper, and yield tables are employed, a constant routine is necessary to prevent discrepancies between cruises, appraisals, and working plans.

Earlier Classifications

It is natural to inquire whether any site classification scheme already existed that might be acceptable. At least 7 site classifications had been developed for species in the territory prior to 1933, and there are now about 12, in addition to the present one. Most of these classifications are useful under special conditions rather than for the region as a whole. All but one divide the territory according to scales based on the height of a single species, usually growing in young, even-aged stands. The single exception (3) for mixtures is limited to young, even-aged stands.

1/ Numbers in parentheses refer to Literature Cited, p. 20.

Of the old-growth standards, only one has been used to such an extent as to affect a substantial body of records and plans. This scheme probably originated with Bruce's (4) proposed classification for white fir volume tables. Modifications in use by the Forest Service adapted the scale to other species. Following the introduction of the site class volume table by Bruce in 1921, many forestry records came to be grouped by site-class. In the present instance, the aim has been to avoid invalidating these expensive volume and yield tables, working plans, and other records by retaining the essential features of the two existing old-growth and young-growth classifications for mixed stands.

The Proposed Classification in Brief

The curves define the midlines of six site-class zones; are harmonized to intercept 25-foot intervals in a height range of 75 to 200 feet at a reference age of 300 years; and are based on 20-year age-class averages in the total height of dominant trees of one or more of the species sugar pine (*Pinus lambertiana*), ponderosa pine (*P. ponderosa*), Douglas fir (*Pseudotsuga taxifolia*), and white fir (*Abies concolor*).

FIELD AND OFFICE PROCEDURE

Data

Records collected for other purposes were used as the basis for the site-class curves. Naturally these measurements are not an ideal sample of the wide range of conditions in the California pine region. From numerous data collected between 1902 and 1929, those groups have been selected that seemed most representative of the site range in the commercial timber belt, giving greatest weight to the measurements on which our principal volume and yield tables are based.

Second growth

The principal second growth measurements came from 220 sample plots taken for the 1933 yield tables in mixed, even-aged stands. These plots were small, averaging about one-fifth of an acre in area. They represented stands of the three upper site classes with ages ranging from 40 to 125 years. Ninety percent of the plots were less than 80 years old. The stands were characteristic of the better portions of the western slope of the Sierra, the majority being located in the Feather and Yuba River drainages. Types represented six of the commonly occurring mixtures of ponderosa pine, sugar pine, Douglas fir, white fir, red fir (*Abies magnifica*), and incense cedar (*Libocedrus decurrens*).

Old-growth

Reliance was placed mainly on the old-growth or virgin forest records included in the seven groups described in table 1.

Three of these groups of measurements--those from Cow Creek, Westwood 2/, and Lemon Canyon--are of special interest because they defined the three principal guide curves for the system.

The groups of old growth tree measurements came from areas differing considerably in size, suggesting the possibility of greater site variation within some groups than others. Most of the field notes give locations only to the nearest land section, whereas distribution of the trees may have been limited to tracts as small as quarter sections or even 40 acres. To be remembered also is the tendency for sugar pine and white fir to predominate on northerly slopes and bottoms, whereas ponderosa pine would be encountered more frequently on the comparatively poorer southerly slopes and ridges. Of the species considered here, all four were present in only one group. Ponderosa pine was best represented in number of trees. Few records were available for the best and the poorest site classes. Personal knowledge of the several localities and the records leads me to believe that none of the chosen groups embraces a range of variations in excess of the regional concept of a site class.

Methods

Field measurements

The old-growth trees were measured as felled in logging. Trees with abnormal tops or incomplete height records were rejected. Ages were determined from ring counts made on the stumps, with the uniform addition of 7 years as an allowance for time to reach stump height. This uniform allowance seemed justified by stem analyses indicating that truly dominant seedlings vary but little with site in the time required to reach stump height. In preparing the guide curves, tree measurements were rejected where stump rot or fire scars necessitated additions of more than 5 years to the number of rings visible. The trees ranged in age from 74 to 660 years, but only about 6 percent of the 3,047 used were less than 100 years old. The form of the curves for young trees offered the most difficulty, and numerous supplementary measurements from permanent sample plots and other sources were used to aid in reaching decisions.

2/ Made available by M. B. Pratt, State Forester of California.

Table 1.--Old-growth data used in preparing site-class curves of figure 1.

Site	Trees	Species	Location	Date
I	247	Ponderosa pine, sugar pine, white fir	Cow Creek, Stanislaus N.F.	1924
I	535	Ponderosa pine, sugar pine, white fir	Shearing Cr., Stanislaus N.F.	1929
II	519	Sugar pine, white fir	Granite Basin, Plumas N.F.	1924
II-III	288	Ponderosa pine, sugar pine, Douglas-fir, white fir	Massack, Plumas N.F.	1912
III	759	Ponderosa pine, Jeffrey pine	Westwood 3/, Lassen N.F.	1913
III-IV	138	Ponderosa pine	Lasco, Lassen N.F.	1925
IV	561	Ponderosa pine, Jeffrey pine, white fir	Lemon Canyon, Tahoe N.F.	1924

3/ Made available by M.B. Pratt, State Forester of California.

Construction of curves

In constructing the system, the uppermost curve was derived from the guide curve for Site I by anamorphosis (5). For Site II, several groups of data produced widely differing curves. The final curve for Site II is a free hand compromise between the two slightly differing curves derived by anamorphosis from the Site I and Site III guide curves. The Site V curve was derived from the guide curve for Site IV.

Choice of the Site Scale

Site range

Choice of the site range for the region was necessarily a somewhat arbitrary procedure based on practices already proved to be convenient and useful, but probable future requirements were not completely ignored. The prevailing concept of site range has been strongly influenced by cutting practices in old-growth stands on national forest lands since about 1906. The best sites, however, are in private ownership, and the very cream of the private old-growth timber doubtless was logged prior to 1906. More recent studies of yield and measurements of piling in second-growth that followed logging between 1860 and 1880 show clearly that there is much forest land better than that we now designate as Site I. Increasing activity in these second growth areas, as well as greater interest in forest practices in the better private old-growth, make it desirable to start the site scale at a higher level than the present standard, 175 feet at 300 years. A fairly definite reference point at the top of the range is the maximum height thus far measured--246 feet for sugar pine. The average for the upper limit should be placed enough lower than this absolute maximum to insure inclusion of a reasonable portion of the territory in the first class. This average has been set at 200 feet at 300 years. A new site class thus is introduced. At the lower extreme the generally accepted poorest site limit of 70 to 80 feet for commercial timber seems to be about right. The average for the lowest class, therefore, has been left at 75 feet.

Number and size of classes

Classes previously used. The number and size of the classes into which the site range is divided also reflect deference to locally established practices. In the first working plan for the region, Barrington Moore (6), in 1913, considered only three site classes necessary for the Plumas Working Circle. Show (7), in 1925, for the Eastern Lassen Working Circle, recognized five sites defined by 20-foot intervals in a range of 70 to 170 feet in the maximum height of old-growth ponderosa pine. In more recent yield tables for second growth, as many as 10 site-index classes are recognized, usually based on 10-foot height intervals at 50 or 100 years. In national-forest timber management, five site classes, based on 25-foot intervals, have become rather firmly established, perhaps because seven of a proposed regional series of volume tables (8) prepared between 1921 and 1925 were related to this scale.

Effects on existing site-class volume tables. The relation between tree form and site, which suggested the site-class volume tables, is not as simple and direct as expected. Partly for this reason, tables for the poorer site classes were never constructed to complete the regional series, but a new series, range-wide in scope, was constructed in 1928, under Bruce's direction, for ponderosa pine. The site range in this series was divided on the basis of merchantable length in 16 foot logs. Unfortunately, the intervals were not readily adapted to local work, and the new tables for the better sites were not generally accepted, the local ones continuing in use. The need of tables for the poorer site classes gradually became critical and, as an expedient, the Site IV and Site V ponderosa pine tables of the 1928 range-wide series were adopted for local Forest Service timber surveys (9).

Range wide site-class volume tables also were prepared for Douglas-fir by Meyer (10) in 1932. No consistent relation between form and site was apparent in the extensive Douglas-fir records, which included some 7,000 trees from 85 locations. As a consequence, Meyer made separate tables for only two divisions of the Douglas-fir range--the Cascade Range and the coast region of the Pacific Northwest, combining Sites I, II, and III; and the more inland distribution of the Sierra Nevada, the Blue Mountains, and the Rocky Mountains, embracing Sites IV, V, and VI. The California records all fell in Site IV. The site-class scale in this case was the one previously used by McArdle and Meyer (11) for second-growth Douglas-fir--30-foot intervals in the average height of the dominant and codominant trees at 100 years. This scale, also, was at variance with California custom, and local practitioners continued to use an earlier favorite, a general California table constructed in 1911.

Use of one table for all sites also remains the rule for old-growth incense cedar, red fir, and some other species. Adding to the confusion, numerous tables have been prepared and used for second-growth of all species without reference to site. There are in the region approximately 90 volume tables for various species, age classes, products, and standards of utilization that are still considered of some utility. Also, there are numerous taper tables, some prepared without regard for volume tables derived from the same measurements, so that volumes calculated from the tapers differ from the volumes computed from the tables.

The confusion prevailing in the volume table situation is a natural consequence of much uncoordinated work by numerous persons and agencies. Work on volume tables, even though uncorrelated, probably will continue, one reason being that appraisal methods require more properly related volume and taper tables. The attainment of some semblance of order is a remote possibility contingent on support for a comprehensive fundamental study of tree form. Until general revisions based on some unity of principle can be undertaken, further confusion will be avoided by maintaining the present site-class scale.

Relation to yield; even-aged stands. Yield and growth properly should determine the site scale. The presumed form-site relation was able to usurp this prerogative because, until recently yield tables were based on young even-aged, normal stands. There being little of such timber in California, and only minor use of what exists, the tables and site scales received little attention. Growth records are now available for the more characteristic understocked forests with great range in composition and age.

Relation to growth; selection stands. Records in such stands covering a period of 20 years show the usual strong correlation between annual growth in board feet and site quality, ample justifying distinction of several site classes. By chance, these records support retaining the size of the classes already used in connection with volume tables, for they show that differences in growth are not significant for intervals smaller than 25 feet at 300 years. The growth records for selection stands obviously do not cover the entire site range, and it has been necessary to rely on the more comprehensive height data in fixing the number of classes at six.

Relation between young- and old-growth scales

The possibility of easy cross-reference between young- and old-growth sites is an important consideration in selecting a site-class scale. Unfortunately, the curves of a site-class system are not so simply related as to permit direct reference by graduated intervals from one index age to another. The difficulties, as encountered in young plantations, were discussed by Bull (12) in 1931. The present curves, adjusted to a constant interval of 25 feet at 300 years, intercept intervals varying from 16 to 21 feet at 100 years, and 10 to 17 feet at 50 years. Conversely, if adjustment is made to the most commonly accepted interval of 10 feet at 50 or 100 years, the intercepts vary at maturity.

Perhaps a desirable ultimate solution of the difficulty would be to abandon the equal interval. Presumably the most logical objective of site distinction is to group lands into equal classes of yield capacity. Sparhawk's committee recommended equal subdivisions of the mean annual growth range at age of culmination. Usually this would mean letting the height intervals vary. The prevailing practice of grouping yield plots according to a uniform height scale imposes unequal differences in tabular yields for even-aged stands. In such stands, a given increase in site index is accompanied by a greater increase in yield near the middle of the range than in either the upper or lower portions. In our mixed selection stands, however, periodic annual growth in board feet per acre fortunately does show an essentially straight-line progression with change in site, a circumstance admitting equal intercepts for both growth and height scales.

Site class versus site index

The tendency to favor equal height intervals probably is a consequence of adhering to the principle of the site index in preference to the site class. Equal spacing of the curves simplifies reading a site-index scale in feet. But acceptance of the index principle tacitly invites site distinctions to the nearest foot with the implication that such fine subdivisions are practical and useful. At best, site determination by height indicators is the result of a series of approximations based on personal judgment, and neither great accuracy nor consistency is to be expected. Although small differences in average height can be detected by increasing the intensity of sampling, the greater cost involved is not justified by a commensurate gain in accuracy of the growth forecasts, for the reason that height index explains only 18 percent of the variation in growth in these selection stands. For most present-day forestry purposes, classes corresponding to about 10 feet at 50 years, 15 feet at 100 years, and 25 feet at 300 years may be small enough. The scale proposed here probably comes as near as can be expected to providing such classes.

Reasons for the 300-year reference age

Disadvantages of tallest tenth as reference. The index age of 300 years has been adopted for a number of reasons. The former criterion for old-growth was the average height of the tallest 10 percent of any trees measured. This was based on the assumptions that the trees of the upper tenth would be dominants; that they would be mature, or beyond the age of appreciable height growth; that 10 percent would be enough for a good average; and that the upper tenth would be a fair sample. Experience has brought out the need for a more discriminating selection of dominants, notably for culled or cut-over stands. Also, the taller trees automatically selected varied in age from about 200 to over 600 years, and in this age range the height increase is enough to cause errors of a site class. As to reliability of the sample average, 10 percent of whatever number of trees happened to be available might be enough, too few, or too many, with accordingly undesirable variation in the reliability of the site determinations. Finally, selection of the upper tenth always results in classifying the site too high because the sample includes only the exceptional trees growing in the most favorable situations--lower slopes, flats, and depressions--not representative of the entire tract. The tallest tenth criterion, therefore, was abandoned in favor of the average dominant of determined age.

Curve position shifted to middle of zone. While making this change, it was important to retain the familiar concept of the site classes and to avoid revising volume and other tables. When age-height curves were drawn for the dominant trees on which the volume tables are based, it was found that these curves intercepted approximately the recognized site-class limits of 75, 100, 125, 150, and 175 feet at about 300 years. Comparatively minor changes were necessary to adjust the set of curves of these intercepts exactly. It should be noted that the change in reference from the tallest tenth to average height at 300 years resulted in shifting the averages for the site-class zones a half class downward. Thus, Site II, instead of lying between 150 and 175 feet at maximum age, with average about 162, now lies between 137 and 162 at 300 years, with average about 150 feet.

Mature dominants less variable than young. The 300 year reference age also was favored because of the fact that height age curves are extremely variable in form through the early age classes including 50 and 100 years. Dominant trees of 50 or 100 years that have grown under optimum stocking are much nearer their predestined ultimate height than those that have experienced more competition. The upper site index curves derived exclusively from young dominant trees, especially from even-aged optimum stands commonly chosen for yield tables, apparently show absurd trends towards impossible heights at older ages. Certain groups of trees in the present data that fall in a single site class on the basis of dominant heights at 300 years or older would fall in three sites on the basis of the 100-year dominants and in four sites with reference to the 50-year dominants. Comparisons of the height deviations by age classes show that the within group variation is no greater for the younger than for the older dominants. The inconsistencies could result from inclusion of more than one site class in a group with the age-class distribution restricted by site--a very improbable coincidence not supported by observation, as mentioned before. The vagaries in form of the lower sections of the curves apparently reflect between group variation in stocking and competition. In the limited instances where yield tables for even-aged stands can be applied, the special site-index curves on which the tables are based should be followed without attempting to translate one scale into another. In the more frequently encountered irregular stands, the choice of older trees near the 300-year reference age should avoid the larger, between-group variations.

Disadvantages of high reference age can be overcome. Disadvantages of the higher reference age are the scarcity of well-formed older dominants, especially in cut-over stands, with the chances in favor of their becoming even fewer, and the difficulties of determining the ages of large trees. Although selecting sample trees near the 300-year age class where possible will result in classifying sites most nearly in harmony with present concepts, where only younger dominants are available, no greater errors should result in selection stands from use of these curves than from curves referenced to 50 or 100 years. As old-growth declines in importance, concepts of site doubtless will change under the influence of increasing familiarity with yields at the lower rotations, whereupon currently used tables, as well as site graphs may be abandoned.

Where practicable, the site class should be determined while felling is in progress so that age counts on the stumps and the corresponding height measurements on the larger trees can be made without having to use either the increment borer or the hypsometer. A land subdivision record of all site determinations, perhaps on a key map, would prevent discrepancies arising from the personal variable or cutting and other stand changes and would insure constancy of the old-growth datum.

Designations validate existing titles

The designations decided upon for the site classes require explanation. Consistency in the endeavor to avoid confusion with respect to existing tables and records requires that titles and terminology be maintained in effect. The newly introduced highest site class, therefore, has been designated "Site A" in order to retain the present significance of Sites I to V. Both the Roman numeral and the average heights corresponding to the classes have come into common use. Since neither one alone is sufficiently descriptive, it is suggested that both be included. Thus, from best to poorest, the classes become Site A-200, Site I-175, . . . Site V-75. Sample averages should not be reported to the nearest foot but should be given the site designation of the curve nearest along the ordinate for the age, differences of less than half a site class being ignored in application.

APPLICATION

The characteristics of the data and the methods of construction as described above should be relied upon mainly as a guide to application of the curves. Something additional needs to be said respecting limitations of territory, types, stands, and sampling procedure.

Territory Covered

Although these curves are founded mainly on trees that grew on the west slope of the Sierra Nevada, they should be applicable to other sections of the so-called pine region such as the east slope of the Sierra; the Warner Mountains; the volcanic plateau in northeastern California; the Cascade System south of the California border; and the northern inner Coast Ranges. The humid coastal redwood region and the boreal spruce-fir types of the northwest coast contain Douglas-fir, but the trees there grow on a grand scale not matched on sites of the interior.

Forest Types

In applying this site classification the term "mixed conifer" in the title is to be interpreted freely to include the multiple combinations of ponderosa pine, Jeffrey pine (*Pinus jeffreyi*), sugar pine, white fir, Douglas-fir, and incense-cedar, and the limited, nearly pure stands formed by some of these species.

Character of Stands

Selection and even-aged

The curves are intended primarily for the so-called selection stands wherein the age classes are usually represented by tree groups of varying size. For extensive general surveys and comparisons they should be suitable also for the even-aged stands encountered. True even-aged stands are comparatively rare and are usually of small extent. For the more important of these exceptional stands, special yield, volume, and site-index tables are available and should be used.

Cut-over stands

Some rather meager records support the belief that curves based on dominants reserved after light or moderate cuttings will have the same form and will yield the same site-class values as curves based on the original stand. This apparently is not true where cutting was heavy and the reserve is less than 20 percent of the original volume.

Density of stocking

Density of stocking in relation to site determination merits careful consideration. Height growth is normal in moderately stocked stands and is appreciably subnormal in both extremely dense and very open stands (13). Complete dependence on the height index unavoidably results in confusing, to some extent, variations in stocking with changes in site quality. This probably explains, in part, the anomaly apparent in normal yield tables--the progressive increase in number of trees to the acre for a given age class as site quality decreases. Safe limits in the range of normal stocking for site determination cannot be specified for selection forests. The only normal density indices available are for even-aged stands and, as suggested above, these indices themselves are dependent on the height scale. Also, the degree to which extremes in density affect height growth is not known, even approximately, for any of our species. Furthermore, it is often not enough to know age and density at the moment of site determination--the history of stand treatment also is important. For example, thinly spaced dominant trees, isolated but a short time by cutting, provide satisfactory indicator samples, whereas long isolated or naturally sparse trees do not.

Thus success in selecting height samples that are reasonably free from the influence of abnormal density depends mainly on individual experience and interpretation. Extremely dense, stagnated stands as well as extremely thin orchardlike stands can be avoided. The younger groups and stands in the throes of competition are perhaps most sensitive to overstocking, are most variable, and hence, least reliable. Sampling several age groups is desirable and, when disparities are obvious, the site indicated by the older groups is to be preferred.

Sampling

Importance

Obtaining sample indicators that are satisfactory for subdividing land into site classes deserves more thought and planning than are commonly devoted to the procedure. Errors and inconsistencies are prevalent and of serious proportions. Adherence to the long recognized fundamental principles of sampling would prevent the more serious mistakes. Beyond this, few special procedures can be recommended for the reason that the form of distribution of site quality and the factors controlling it are not well known. Two aspects of the sampling problem are discernible--the one having to do with size, shape, and other characteristics of the land subdivisions, or getting good averages for the site qualities; the other concerned with behavior of the indicator species within a given site quality. Less is known about the land aspects--somewhat more about the trees.

Prescribed conditions

For larger tracts, it frequently happens that the nature of the subdivisions for which site ratings must be made is unknown until after an extensive survey is completed. Type, age class, and other boundaries may be fixed by mapping as the survey progresses, or may not be determined until after the notes are compiled. In such cruises, the site indicator measurements are taken concurrently with the stock and other data. With these prescriptions, the best that can be done by way of planning is to insure enough records of adequate distribution for the most exacting of reasonable subdivision schemes.

Small plot work introduces the simpler problems in site determination. Here the land aspect merges with the indicator phase about which most is known, for there is little chance of a small plot's containing more than one site quality, and age classes and types are restricted. It is necessary only to sample the indicator trees. These are the conditions represented by our basic data. A study of variation therein serves as a guide to the number of trees that should be measured. With due allowance for height-age regression, 5 to 15 trees are enough to determine the site correctly 19 times out of 20.

Areal unit of sampling

A sampling procedure is suggested by the simplest case of the small plot. If we can agree upon the dimensions of some small plot to use as a standard, or sampling unit of site quality, the indicator can be sampled within these units by taking 5 to 15 trees in each, as noted above.

The sampling unit should be small enough to avoid including too frequently more than one site. Too small a unit in open stands frequently would not include the minimum of 5 indicator trees. Very small plots also would multiply excessively the number of tree samples required. Experience in plot work shows that square tracts up to 10 acres in area, with site range less than a class interval, are of common occurrence even on variable topography. Twenty- to 40-acre plots are fairly easy to find on the more uniform northeastern lava plateau. Twenty acres is the smallest unit for which it would be practicable to keep separate notes in cruising by the usual 10-percent coverage. The long, narrow shape of such 20-acre plots is not ideal, but it would seem better to accept this unfavorable feature than the large size of 40 acres, the first convenient square. Units of 20 acres can be combined exactly for most subdivisions conforming to public land lines, and with compensating nonconformities for irregular subdivisions. It is suggested, therefore, that the 10 x 20 chain, 20-acre tract be accepted as the areal sampling unit for site quality and that the indicator sample be selected on the 1 x 20 chain strip in each unit.

Selecting areal and indicator samples

The ordinary timber cruise is a systematic survey. The advantages in economy and accuracy of systematic strip sampling have been demonstrated for determining volume (14) and area of irregular types (15), and by inference, the same system should be satisfactory for collecting the areal, or site quality sample units. With regard to the indicator sample, any routine adopted should favor randomness with respect to age classes and species as well as uniform distribution along the strip. These conditions probably would be satisfied approximately if the one most suitable tree nearest the compass line were selected in each 4-chain interval of a strip. Schumacher and Chapman (16) call attention to the bias in favor of open-grown trees introduced by this method of selection. For present objectives, the averages probably would not be affected appreciably. The tendency would be counterbalanced to some extent by suggested precautions to insure dominance and moderate stocking.

Choice of true dominants

The sample trees should be true dominants (17) relative to other trees of the same age class. If the Region 5 tree classification (18) is followed, the trees should be from classes 1, 3, or 5. The term "dominants" should not be construed to include codominants, as sometimes is the practice. The admission of codominants was favored by Sparhawk's committee. The inclusion of codominant trees incurs the additional obligation of insuring representation of the two crown classes in the sample in the same proportion as they occur in the stand on the sample area. It is not practicable to do this concurrently with cruising mixed, group-selection stands where the proportion changes rapidly with age, composition, and stocking. For cruises made with the intention of using the locally developed growth-predicting mechanism, only the dominants need be distinguished in the records; hence reliance on this crown class for site indicators avoids a special tally. The dominants are usually easy to recognize, whereas the admission of codominants is conducive to quibbling over marginal trees and leads to inconsistencies in site classification. Since the codominants compensate in no way for their disadvantages, nothing is lost by their exclusion. Decision as to dominance is simplified by picking the trees from groups. Here the crown-class relation is most obvious and there is apt to be evidence indicating whether dominance and moderate stocking have prevailed from the beginning.

Age determination

Determining ages of the sample trees can be reduced to a simple procedure practicable even for most cruising. This is true because relatively large errors in age of 12 to 50 percent introduce small risk of missing the site class; consequently the number and length of borings for ring counts can be reduced considerably by resorting to partial or complete age estimates.

Permissible errors. The range of error in age admissible without missing the site class increases with increasing age and with decreasing site quality. Because of the form and relation of the curves, negative or low estimates of age are more to be guarded against than positive errors. As a rough guide, the maximum allowable negative departures from certain age-class averages are shown in table 2.

Age from borings at breast height. For trees 100 years old or younger, where ring counts will usually be necessary, the radii will fall within the span of the increment borer except on the best sites. For the larger trees, counts from the longest cores attainable may be supplemented with estimates for the remaining sections of radius. This will involve attention to such details as measuring diameter, single bark thickness, and core; calculating the remaining section of radius; estimating the rings therein; and adding estimate and core count.

Age counts from borings at breast height must be converted to total ages by adding the number of years required to grow to the height of 4.5 feet. The time varies from about 6 to 16 years according to site, but to make a variable adjustment would require an undesirable preliminary estimate of site quality inself. It would seem least prejudicial to the final estimate if a constant conversion factor, such as 10 years, were added.

Age estimates. When refinements are not advisable, where the timber is very large, or for other reasons estimates of age must be relied upon entirely, indicator trees should be favored that are near the reference age of 300 years where errors of 20 to 50 percent are permissible. If circumstances require using the average height at the estimated mean age for a whole tree class, class 3 or class 5 is to be preferred. It is sometimes the practice to enter the curves with the average height of the class 3 trees at the 300-year upper limit instead of the average age. This may result in missing the site class if the quality is high. In one instance of record where tree classifications and age determinations were made independently on the same large trees, 32 class-3 pines averaged 251 years old, and 158 class-5 pines averaged 348 years. When resorting to estimates of age, it is well to remember that ponderosa pine and sugar pine are less deceptive than white fir and Douglas-fir. Errors were compensating for the pines but tended to be positive for the other species.

Species indicators compared

All four species apparently may be used safely, without distinction, as site indicators. It should be noted that this conclusion is contrary to earlier recommendations. Schumacher (19) in his study of white fir yields, concluded that sugar pine dominants in even-aged stands 45 to 150 years old were shorter than dominants of the other species by 2 to 8 percent. The earlier study (3) of mixed, even-aged second growth, based partly on Schumacher's plots, apparently affirmed this conclusion, disparities being reported as large as 10 percent.

Table 2.--Maximum negative departures from age-class averages allowable without error in site determination

	Age class, years			
	50	100	200	300
Site class	Negative departures, years			
A - 200	6	16	35	65
I - 175	6	15	40	70
II - 150	6	15	40	75
III - 125	6	16	45	90
IV - 100	7	16	50	110
V - 75	9	20	70	150

Results of the present old-growth study, more recent information from permanent plots, and review of the earlier second-growth records lead me to believe that the conclusion is incompatible with behavior of the species and that a distinction between them is not justified.

The records for the older timber used in this study show that sugar pine is, if anything slightly taller than the other species at comparable ages, but the differences between the four species are not large or consistent enough to be accepted as significant or important.

Regular observations of numbered trees over long periods indicate that sugar pine, once behind in the race with fir, continues to decline if unassisted. Superior trees in older stands usually have been dominant from the first or were released early in life. It is well established by thousands of measurements that sugar pine in mature mixtures does attain maximum heights above any of its common associates. This fact is not to be interpreted as proving its ability to outstrip other trees in fair competition, for the tallest sugar pines exceed in age the tallest trees of the other species from a few to as much as 140 years.

The inferences that might be drawn from uncritical comparison of the second-growth and old-growth records have important management implications. If it were true that sugar pine, even though subordinate in young stands, could improve its position, eventually becoming dominant by surpassing in height growth such competitors as the more tolerant white fir, out whole concept of mixed-stand silviculture would have to be revised. The unnaturalness of the conclusion that the comparatively intolerant pine could be consistently shorter than fir and still be dominant suggested some fiction in the crown classification. This suggestion was supported by the recollection that the dominants were to be the tallest trees by specification; hence, an impartially selected fraction of them could not logically average 10-percent shorter than the whole. For these reasons, instead of adopting the simple expedient of omitting sugar pine from the site sample, the second-growth records were reviewed.

This review indicated that the apparent disparity in height between the species resulted from an inadvertent bias in the field methods used in the mixed second-growth study. This bias entered through unintentional shifting of the criterion of dominance between the species. The intention was to measure heights for the dominants of average diameter. Unfortunately, in practice the diameter of the average dominant was taken independently for each species rather than for all on the plot as a whole. This procedure operated to the disadvantage of sugar pine, because this species was nearly always a minor component of the stands and, in the 50 to 60 year age-class where most of the plots were concentrated, was beginning to suffer severely from competition with fir. Thus, sugar pine was poorly represented in the upper range of diameters. As a consequence, failing sugar pines of smaller average diameter were pitted against larger firs higher in the scale of dominance. When a comparison was made for 61 plots representing age classes of from 45 to 125 years, where heights of all species were measured at the same points in the range according to the criterion of equivalent diameters, sugar pine dominants averaged 87.0; ponderosa pine, 86.2; Douglas-fir, 83.2; and white fir, 84.7 feet. These differences are not large enough to excite serious concern in making the rather general site distinctions contemplated. Evidently the species may be averaged together provided the definition of dominance is applied impartially.

Incense cedar, an almost constant associate of the four species discussed here, often exceeds the others in numbers but is always inferior to them in stature. On cut-over land where defective cedars are sometimes the only remaining trees, one should not place dependence on this species as a site indicator.

Accuracy of measurements

Height measurements should be made within reasonable limits of instrumental error--perhaps about 2 percent. This can be accomplished easily with the Abney level and tape.

Indicator trees to be of normal form

Trees with normal undamaged tops should be selected for the sample height measurements. The choice need not be restricted to trees with pointed crowns. Older round or flat-topped trees are admissible where the condition results from natural decline in height growth rather than from forking, breakage, or mistletoe and insect damage.

Number of indicator trees required

The numbers of sample trees necessary for averages of specified reliability are approximately equal for the several site classes. With respect to age, because of varying width of the site-class bands, the numbers required decrease rapidly from 50 to 150 years and are then fairly constant to higher age classes. The figures in table 3 for Site I--175 and Site III--125 are indicative of the numbers of trees necessary for all sites at various ages to insure averages that will fall in the proper site-class zones 19 out of 20 times. These numbers are to be considered as minima where ages are known within limits of 1 to 5 years.

Calculating the indicator average

In combining measurements for a general site indicator, decision as to the site class will be expedited if weighted averages are used instead of curves plotted from the sample trees. Weighting should be accomplished through reference to figure 1 by multiplying the height in feet of the nearest curve at reference age 300 by the number of trees in the site-class zone. The combined indicator should be reported by the designation of the nearest site-class curve rather than by the actual average in feet. For example: If the ages and heights of the sample trees on a 20-chain strip were 100 years x 80 feet, 210 x 122, 200 x 127, 255 x 112, and 105 x 90, the indicator average would be

$$\frac{(4 \times 125) + (1 \times 150)}{5} \quad \text{or}$$

130 feet, and the site class would be reported as III-125.

Merchantable length not a substitute for total height

Merchantable length, or height to a fixed top diameter, is frequently used erroneously in computing site indicators. A common fault is to convert the number of 16-foot logs to feet, add some number for the average length of top above the fixed diameter, and use the sum for reference to site-class curves based on total height. The trouble with this procedure is that proper average additions for top length are practically indeterminate. The top section varies with species, top diameter, merchantable height, age, diameter at breast height, and with the object of estimate--site quality. The attempted correction therefore implies a prejudicial advance estimate of site. A related mistake is to use interchangeably site-class scales in equal intervals of merchantable length and equal intervals of total height.

Table 3.--Number of sample trees required for height averages indicating the correct site class 19 times in 20

	Age class, years								
Site	50	100	150	200	250	300	400	500	600
	Number of trees								
I - 175	14	11	8	7	7	6	6	5	5
III - 125	18	10	9	6	5	5	5	4	4

It may be supposed that one could prepare merchantable height curves intercepting variable intervals at the reference age and so correlated with the equal-interval total height curves as not to change the concept of site in terms of predicated yields. One objection to this proposal is that for mixed stands more than one set of curves, perhaps one for each species, would be necessary.

The use of merchantable height for site reference in any manner is probably at variance with the height-indicator principle. Resort to the utilization standard implies a shift in the biological concept of crown class and involves a departure from the definition of dominance. Regardless of apparent convenience, converting one standard to terms of the other is an unsound procedure. In the long run, it will be found more efficient, more consistent, and more nearly accurate to measure the total heights in the field especially for site determination.

Site Classification is Justified as a Special Project

In truth, where land is not already well classified, making site determination a special undertaking will pay dividends in better forest management. Sharp distinction of the more productive areas will aid in correcting the prevailing almost indiscriminate distribution of effort to the good, the poor, and the indifferent soils alike which characterizes the poor management of pioneer forestry. Dispersal of forces--a little everywhere but nowhere enough--cannot stem the tide of drain from fire, insects, disease, brush invasion, and improvident cutting. Intensification of forestry can be accomplished at no greater cost by localizing the effort. Site classification will show where.

SUMMARY

Site classification curves are presented (figure 1) for the mixed-conifer selection forests of the California pine region, with enough description of data and methods of preparation to enable correct application. The object is to establish a single criterion of site as nearly as possible like the one now in use for volume surveys, growth forecasting, and other forestry work.

The classification is based on the height-age relation for dominant trees of one or more of the four species, ponderosa pine, sugar pine, Douglas-fir, and white fir.

The site range is divided into six classes represented by 25-foot intervals of average total height of true dominants at a reference age of 300 years. This scale divides the range in production capacity by equal intervals of periodic annual growth.

The site classes are designated, from best to poorest, A-200, I-175, . . . V-75. The curves define the midlines of the site-class zones.

The territory covered includes the Sierra Nevada, the lava plateau in northeastern California, the Warner Mountains, the Cascade System south of the California border, and the northern inner Coast Ranges, but not the redwood or northwest coastal sections.

Types for which the curves are adapted include varying combinations of ponderosa pine, Jeffrey pine, sugar pine, white fir, Douglas-fir, and incense-cedar, and the limited, nearly pure stands formed by some of these species.

The classification is intended primarily for the irregular, grouped selection forests but for general plans and surveys may be applied to the occasional even-aged stands encountered. It is unsuitable for extremely dense stands or stands that have always been extremely open. It can be used on cut-over land with moderate to heavy reserves where some true dominants are left.

To obtain the general site class for a large tract it is suggested that areal sampling units not larger than 20 acres be taken systematically. A minimum sample of 5 trees, obtained by measuring one well-formed dominant near the reference age for each 4 chains of strip, apparently would give the correct site class for the areal unit 19 times in 20.

The number of sample trees of determined age per areal unit required for height averages in the right site class 19 out of 20 times varies from 15 at 50 years to 5 at 300 years. Heights should be measured with an Abney level and tape. Ages should be determined to the nearest 5 years if the trees are around 50 years old, but errors as large as 60 years are permissible if the trees are 300 years old or older.

Merchantable heights to a fixed top diameter cannot be converted satisfactorily for reference to this site classification.

Site classification, by showing where to localize effort, contributes to intensification and greater efficiency in forest management.

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