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A TREE CLASSIFICATION FOR THE SELECTION FORESTS OF THE SIERRA NEVADA[1]

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INTRODUCTION

Individuality in man is accepted without question. In domestic animals, also, good and bad individuals are generally recognized. Even in some cultivated plants—orange trees and rubber trees—the poor producers are searched out and eliminated. Indeed, individual variability is a normal condition in all groups of organisms. Yet forest trees are rarely thought of in terms of the individual. Forest products are seldom of sufficient value to justify tending the individual tree. But there is no more reason why two western yellow pine trees should grow with equal rapidity or bear equal amounts of seed because they grow under identical conditions than that two men should attain equal strength or equal mentality because they receive the same food. When to inherent variability are added the effects of a wide range of interrelated environmental factors, the great differences in the behavior of individual trees can be readily appreciated. It is adjudged a common fault to lose sight of the forest through confusion of the trees. Much more frequently in forestry the mass effect is the more obvious, and there is failure to see in their proper relationships the elementary components of the forest—the individual trees.

EXISTING TREE CLASSIFICATIONS

Thus far, within the species, foresters in the United States have necessarily been limited in the classification of trees to only slightly less generalized groups of individuals defined by differences in vigor or value. Dominant, codominant, intermediate, and suppressed, or some such classes based upon position in the crown canopy, are universally recognized. In European countries, where forestry has become most intensive, the necessity for distinguishing more clearly these differences in vigor and value has led several foresters to consider not only position in the crown canopy but crown development and stem form as well.

In Germany in 1884 G. Kraft formulated a tree classification based on crown development (*6*).[2] This was amplified in 1897 by C. R. Heck (*4*), who distinguished stem classes within each crown class. Marked differences in growth (*5*) and seed bearing (*14*) between these tree classes have been clearly determined from the study of sample plots over long periods.

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[2] Reference is made by number (italic) to "Literature cited," p. 770.

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In 1902 German forest research institutions agreed upon a tree classification to be used in thinning research (*9, p. 200*). In Switzerland, France, Denmark, Finland, and Sweden the question of tree classes is also dealt with extensively in the literature of thinning. The late Gunnar Schotte in the publication of the Swedish State Forest Experiment Station in 1912 gave a review of tree classifications hitherto in use, and added one of his own based partly upon position in the crown canopy, partly upon crown development, and to a lesser degree upon stem form (*12, 8*).

THE NEED FOR A NEW CLASSIFICATION

All these classifications, so far as known, apply to even-aged stands, for the most part well stocked, and of comparatively simple composition. In the pine stands of California the situation is complicated by irregularity in age, understocking, and mixtures of several tolerant and intolerant species. In addition to position in the crown canopy, crown development, and stem form, the age of each tree must be considered in any grouping based on capacity for growth and seed production. The conventional crown classification applicable to even-aged stands, if recognized at all, is an unsatisfactory index of vigor under these conditions. In the western yellow pine stands of the Southwest some improvement has been effected by the recognition of two broad age classes—"blackjacks" and "yellow pines" (*7*). In California a rough segregation of age classes is now practiced in marking, but is recognized to be inadequate. Selection by diameter limits is a poor makeshift, to be used only when marking is not feasible.

The history of older Forest Service cuttings and examinations of marking on several of the most important recent sales indicate clearly that there is still lack of reasonable uniformity in the application of the same marking principles in similar stands. At the same time there is a lack of adaptability in applying the principles to varying conditions. Incorrect marking has frequently resulted in rates of growth much below the capacity of the site. Far too many unproductive trees are being retained.

The policy of the Forest Service in the California pine region is to reserve 20 to 30 per cent of the original stand in sound thrifty trees capable of good growth and likely to survive windfall, insect attacks, or fire, to make feasible a second cutting in comparatively inaccessible areas in reasonable time. A considerable portion of this reserve must be high-quality timber, and this necessarily means retaining rather large trees. As a source of seed in case the advance reproduction should be destroyed by fire, four or more seed trees per acre, also of rather large size, must be left. Far more skill is demanded in marking for a large reserve than for a heavy selection or seed-tree cutting. On many cuttings the provision for reservation of a certain percentage of the stand has been too strictly followed, with insufficient consideration for the condition of the stand or site variations. A recognized system of tree classification would no doubt result in uniformly better marking. As a basis for comparison of marking jobs in sales inspections such a system has obvious advantages.

Forest entomologists have demonstrated that the western pine beetle (*Dendroctonus brevicomis*) has a definite tendency to select certain trees in endemic infestation.[3] A clear definition of the susceptible types of trees would permit their elimination by marking, and thus greatly reduce this important source of loss.

In studies of sample plots in selection stands where records are made of individual trees, a uniform system of tree classification is needed to simplify recording and permit accurate comparison of one area with another. E. J. Hanzlik has suggested using the Swedish system developed by Schotte for such work (*3*). For sample plots in even-aged stands this system doubtless works well, but omission of the age factor makes it unsuitable for application in selection stands or in cut-over areas.

A workable tree classification also offers interesting possibilities in appraisals, in marking to maintain certain standards of growth, in predicting future yields, in studies of susceptibility to fire damage, and in many other ways in which simple crown classes are now used in even-aged forests.

Whatever system of tree grouping is used in marking, it is not to be expected that there will be perfect agreement between different men. Border-line trees will be encountered in this work, just as they are in applying the accepted classifications for even-aged stands. Adherence, however, to a definite system of appraising each tree, based on easily discernible characteristics, will prevent obvious mistakes in marking, and so will raise the average rate of growth in cut-over stands, decrease losses, and improve the quality of seed trees. Agreement on a well-defined terminology is essential to mutual understanding.

BASIS FOR CLASSIFICATION

The conclusions presented here are the results of 15 years' observation of more than 20,000 numbered trees in 25 permanent sample plots covering about 300 acres, established on typical sale areas in the Sierra. Detailed crown and bole descriptions permit segregation of the trees into the classes to be described below. On this basis comparisons of growth and seed bearing have been made from measurements taken at five-year intervals. For the sake of brevity, the results for only one species, western yellow pine (*Pinus ponderosa*), are given. This species occurs on all the plots in numbers sufficient to give a reasonably good basis of data. It is widely known, and is more easily grouped into the proposed classes than any of the other species.

The proposed classification represents an effort to segregate into groups the trees with certain combinations of characteristics that are known from previous studies (*1*, *2*) to have similar influences on growth or seed bearing. It is obviously impossible to consider each of the interrelated variable elements singly. The significance of any one factor can not be isolated. Practice demands that the number of classes be small and that the factors on which they are based be readily distinguishable. In actual field tests of this system no serious difficulties have been encountered by the men, even though they had little previous knowledge of the grouping.

The major factors considered in the make-up of these classes are:

1. Four general age groups—young (less than 50 years), thrifty mature (50 to 150 years), mature (150 to 300 years), and overmature (over 300 years).

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[3] Carefully controlled experiments have recently been conducted by H. L. Person at North Fork, Calif., on behalf of the Bureau of Entomology. A report of these studies is in preparation for publication in the Journal of Forestry.

2. Degree of dominance within these age groups, expressed in terms of the conventional crown classes—isolated, dominant, codominant, intermediate, and suppressed.
3. Crown development.
4. A supplementary estimate of thrift designated in three degrees of vigor—good, moderate, and poor.

The estimate of vigor is based on apparent age, degree of dominance, crown development, and, in addition, the density and color of the foliage, the form of the top (whether pointed, round, or flat), the size attained in relation to age, the color, thickness, and texture of the bark, and freedom from disease.

In marking, only sound, well-formed trees need be considered in such a classification. It is deemed undesirable to introduce complications in the form of subclasses for the multitude of defects which may possibly occur. The question of merchantability assumes priority and should be considered separately on the basis of already well-established criteria. Trees that are malformed, injured, or diseased should be removed from the stand wherever possible, and it is unnecessary to go further in segregating them by thrift classes.

In working up this material an effort was made to determine to what extent mechanical injuries and defects, such as fire scars and logging scars on the stem, fire or logging damage to the crown, broken or dead tops, etc., affect growth. The difficulty of isolating the effects of a given class of defects is apparent. On cut-over areas the number of defective trees has naturally been reduced, so that after division into comparable groups there is insufficient material to be of much significance. Damage to the crown that materially reduces the leaf area is usually reflected in a reduction in the rate of growth. In the present data no consistent relation is discernible between mechanical injuries to the stem and deficient vigor. Such injuries, when of sufficient extent to affect growth materially, should influence marking through predisposition to bring about losses and because of their effect on merchantability, rather than through their effect on growth. For purposes of study it is a simple matter to supplement the classification for sound trees with a description of defects that will permit elimination of uncertain influences from the data.

DESCRIPTION OF CLASSES

Seven tree classes are proposed, as follows (see fig. 1):

Class 1: *Age class*, young or thrifty mature; *position*, isolated or dominant (rarely codominant); *crown length*, 65 per cent or more of the total height; *crown width*, average or wider; *form of top*, pointed; *vigor*, good.

Trees of this class are rarely over 30 inches in diameter even on good sites. The bark is dark brown and roughly fissured into ridges or small plates. The foliage is rich green in color and dense, owing to retention of the needles of three to five seasons or more, except at the base of the crown. The needles are often long and coarse, especially near the top. Terminal buds are large. The top is pointed, owing to the rapid elongation of the terminal. Thrifty open-grown young trees belonging to this class are, however, sometimes round topped because of excessive lateral growth of branches near the top. On the other hand, slow-growing trees sometimes have pointed tops, due to weak development of laterals. The annual whorls of branches and internodes are still distinct, except in the lower crown. Branches are horizontal or upward curving, except at the base of the crown where suppression is taking place. Numerous stubs of dead branches are likely to be present below the crown.

Class 2: *Age class*, young or thrifty mature; *position*, usually codominant (rarely isolated or dominant); *crown length*, less than 65 per cent of the total height; *crown width*, average or narrower; *form of top*, pointed; *vigor*, good or moderate.

Such trees are usually less than 24 inches in diameter. They are commonly the inside codominant trees of groups. The crowns are smaller and less dense than in trees of the first type. Otherwise they are similar to those of class 1.

FIG. 1.—Classes 1, 2, and 6 represent young or thrifty mature trees; classes 3 and 4 mature trees; classes 5 and 7, mature or overmature trees. Form of top, crown width and length, and position in the crown cover are other determining characteristics

Class 3: *Age class*, mature; *position*, isolated or dominant (rarely codominant); *crown length*, 65 per cent or more of total height; *crown width*, average or wider; *form of top*, round; *vigor*, moderate.

These trees are ordinarily between 18 and 40 inches in diameter, depending on site quality. The bark is light brown or yellow, with moderately large smooth plates. The foliage is less dense than in class 1 trees. The top is round, because of slow height growth. The nodes are indistinct, because of incomplete whorls of branches. The branches are nearly all horizontal or drooping.

Class 4: *Age class*, mature; *position*, usually codominant (rarely isolated or dominant); *crown length*, less than 65 per cent of the total height; *crown width*, average or narrower; *form of top*, round; *vigor*, moderate or poor.

These are commonly the inside or codominant trees of this age class. Except for their small poorly developed crowns and smaller size, they are similar to class 3 trees.

Class 5: *Age class*, overmature; *position*, isolated or dominant (rarely codominant); *crown* of any size; *form of top*, flat; *vigor*, poor.

These are usually the largest trees in the stand. The bark is light yellow in color, the plates often very wide, long, and smooth, especially near the base. The bark may be thin, having weathered more rapidly than it has grown. The foliage is usually rather pale green and very thin. The needles are fairly short, appearing as tufts on the ends of the twigs. The needles of two or three seasons only may be retained, even near the top. The top is flat, the terminal rarely discernible. There is no appreciable elongation of the main axis. Scarcely any nodes are distinguishable. Nearly all the branches are drooping, gnarled, and crooked.

Class 6: *Age class*, young or thrifty mature; *position*, intermediate or suppressed; *crown* of any size, usually small; *form of top*, round or pointed; *vigor*, moderate or poor.

These are understory trees, rarely over 12 or 14 inches in diameter. The bark is dark and rough. The top is round or pointed, showing that some height growth is taking place. Whorls of branches are evident, though the internodes are short.

Class 7: *Age class*, mature or overmature; *position*, intermediate or suppressed; *crown* of any size, usually small; *form of top*, flat; *vigor*, poor.

These understory trees are rarely over 18 inches in diameter. The bark is light in color, thin, and smooth. The top is flat, the terminal rarely distinguishable. The foliage is excessively thin. The few branches present are gnarled and drooping.

The similarities and differences between these groups are perhaps more evident in the abbreviated comparison given in Table 1.

RELATIVE IMPORTANCE OF CLASSES IN THE STAND

The relative importance of the tree classes in the original and remaining stand and the proportion of the cut supplied by each are shown in Table 2, which summarizes the data from a typical stand in the Stanislaus National Forest cut over in 1923. Marking was carefully done by a marking board to conform as nearly as possible to existing cutting policy.

TABLE 1.—*Summary of tree classification by system proposed* [a]

	Age class	Crown class (position)	Crown length	Crown width	Form of top	Vigor
			Per cent			
Class 1	Y—TM	X—D (C)	65+	M—W	∧	V
Class 2	Y—TM	C (X—D)	65−	M—N	∧	V—M
Class 3	M	X—D (C)	65+	M—W	⌒	M
Class 4	M	C (X—D)	65−	M—N	⌒	M—P
Class 5	OM	X—D (C)	All.	All.	⊓	P
Class 6	Y—TM	I—S	All.	All.	⌒ (∧)	M—P
Class 7	M—OM	I—S	All.	All.	⊓	P

[a] Significance of symbols is as follows:
Age class: Y—TM=young or thrifty mature; M=mature; OM=overmature.
Crown class: X=isolated; D=dominant; C=codominant; I=intermediate; S=suppressed.
Crown width: M=average; W=wider than average; N=narrower than average; All=any size.
Vigor: V=good; M=moderate; P=poor.

TABLE 2.—*Volume and number of trees per acre and percentage of total volume in each tree class in original stand, in portion marked for cutting, and in reserved portion* [a]

VOLUME PER ACRE

Tree class	Original stand		Marked for cutting		Reserved		Percentage of each class marked
	Board feet	*Per cent*	*Board feet*	*Per cent*	*Board feet*	*Per cent*	*Per cent*
Class 1	12,772	16.6	4,373	6.9	8,399	62.8	34.2
Class 2	2,259	2.9	353	.6	1,906	14.2	15.6
Class 3	21,297	27.8	18,407	29.1	2,890	21.6	86.4
Class 4	1,708	2.2	1,708	2.7			100.0
Class 5	37,875	49.4	37,875	59.7			100.0
Class 6	211	.3	51	.1	160	1.2	24.2
Class 7	595	.8	575	.9	20	.2	96.6
Total	76,717	100.0	63,342	100.0	13,375	100.0	82.6

NUMBER OF TREES PER ACRE [b]

Tree class	Original stand		Marked for cutting		Reserved		Percentage of each class marked
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Per cent*
Class 1	34.2	34.4	3.4	15.9	30.8	39.5	9.9
Class 2	7.6	7.7	.3	1.4	7.3	9.4	3.9
Class 3	7.3	7.3	6.4	29.9	.9	1.2	87.7
Class 4	.5	.5	.5	2.3			100.0
Class 5	8.2	8.3	8.2	38.4			100.0
Class 6	37.4	37.6	.2	.9	37.2	47.6	.5
Class 7	4.2	4.2	2.4	11.2	1.8	2.3	57.1
Total	99.4	100.0	21.4	100.0	78.0	100.0	21.5

[a] Board-foot figures give stands per acre for trees 12 inches diameter breast high and over, Scribner Decimal "C" rule. Stanislaus plot 5, cut in 1923.
[b] Figures show number of trees per acre 4 inches diameter breast high and over.

Classes 1, 3, and 5, the large-crowned dominant trees in the three general age groups, here form 93.8 per cent of the original board-foot volume for trees 12 inches in diameter and larger. Classes 3 and 5, mature and overmature dominants, provided 88.9 per cent of the cut. These tree classes contain the highest grade material (*11*), and probably represent more than 95 per cent of the present value of the entire stand. The class 1 trees, immature dominants, which formed 16.6 per cent of the original stand, supplied but 6.9 per cent of the volume cut. Such trees were marked only when it was necessary to thin groups of trees, to facilitate logging, or when they had been badly injured by removal of other trees. Classes 1 and 2 make up 77.1 per cent of the 13,375 board feet per acre reserved, representing very little present value, since they contain comparatively little high-grade lumber. Class 3 trees represent 21.6 per cent of the reserve volume, providing a few larger seed trees and some high-grade material for a second operation.

The small-crowned dominant and codominant trees of classes 2 and 4 and the intermediate and suppressed trees of classes 6 and 7 never form more than a small part of the merchantable volume. In number of trees, however, they are often relatively important. They are of primary interest because of their influence on future yields. The numerical importance of the tree classes in the above stand is also shown in Table 2, with the inclusion of unmerchantable trees between 4 and 12 inches. In this stand, where there was an average of 99.4 trees per acre, most of the trees were in classes 1 and 6—34.2 per cent and 37.4 per cent, respectively. Classes 2, 3, and 5 were nearly equally represented by 7 to 8 per cent of the total. There were relatively few trees in classes 4 and 7.

COMPARISONS OF GROWTH

For the sake of simplicity all the following growth comparisons are in terms of basal area, expressed as average annual rates per cent for the 15-year period. In terms of volume growth the differences shown would be accentuated, since the mature and overmature trees make practically no height growth. The size grouping is based on the diameters at the beginning of the period.

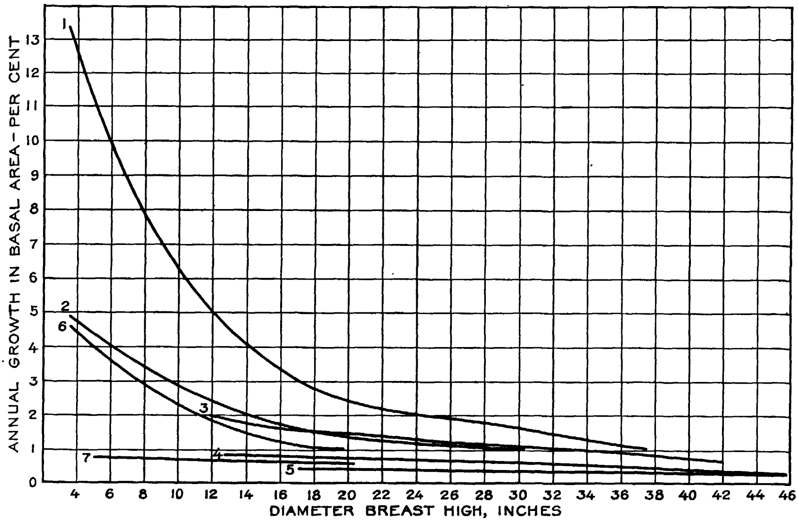

FIG. 2.—Annual basal area growth per cent, by tree classes, western yellow pine, site I (1,183 trees, 1910–1925)

Figure 2 permits comparison of the relative rates of growth of the seven tree types by diameter classes. The graph is based on 1,183 trees remaining on a first-quality site that was cut over in 1910, in the Stanislaus National Forest.

Class 1 trees are superior to the others for all diameters, but especially so in the smaller sizes. Class 2 trees have grown considerably more slowly than those of the first group, but in the smaller size classes are considerably above the trees in the remaining groups. Above 18 inches class 2 and 3 trees have grown at about the same rate, the larger crown area of the class 3 trees offsetting their greater age. The rate for class 3 shows little variation with size.

The trees of classes 4, 5, and 7 show still less variation with diameter, growing at a hopelessly slow rate for all sizes. The younger trees of class 6 give some promise, and the fact that few of them can be cut under present economic conditions is not a serious matter.

It is evident that a good rate of growth can not be expected from mature and overmature trees of classes 3, 4, 5, and 7, regardless of diameter, even on the best sites. Above 28 or 30 inches, differences in rate of growth between the seven groups become unimportant. For these larger trees the risk of loss and seed-bearing ability should govern the choice in marking.

It is apparent from Figure 2 that age is the most important factor to be considered. Crown development and crown class differences are far more important in the young and submature than in the mature and overmature age classes.

A summary of the growth produced by this same stand is given in Table 3. Class 1 trees, which represented but 29.4 per cent of the residual stand, produced 57.7 per cent of the total growth and maintained the highest annual rate, 3.05 per cent. Class 2 trees grew only half as rapidly. Class 3 trees have not justified their retention from the standpoint of growth, and yet the annual rate of nearly 1 per cent is fairly good, and increase in value justifies reserving a considerable proportion of such trees. Little can be said in defense of the reservation of nearly one-fourth of the stand in classes 4 and 5.

TABLE 3.—*Percentage of total basal area in 1910 and total growth 1910–1925 represented by each tree class, with annual growth rate (volume) maintained by each class over the 15-year period* [a]

Tree class	Total basal area, 1910	Growth produced, 1910–1925	Annual growth rate
	Per cent	*Per cent*	*Per cent*
Class 1	29.4	57.7	3.05
Class 2	11.4	11.2	1.53
Class 3	27.9	17.8	.98
Class 4	5.1	1.9	.59
Class 5	18.8	4.3	.35
Class 6	3.7	5.6	2.34
Class 7	3.7	1.5	.65
Total	100.0	100.0	1.56

[a] Western yellow pine, Stanislaus plots 2, 3, and 4. Site I. Cut over in 1910.

A similar relationship is shown graphically for a much larger area in Figure 3.

It should be remembered that the foregoing growth comparisons include the acceleration due to release by cutting, which should have culminated within 15 years after the thinning. The trees which were subordinate in the original stand have not generally improved sufficiently to equal the rates maintained by former dominants. It is usual for higher classes to decline to subordinate classes, but extremely exceptional for the reverse process to occur. Acceleration of growth is a minor consideration in the prevailing type of cutting with its tendency toward grouping of reserves. It is better to reserve trees already dominant than to rely upon the enhancement of increment in understory trees. This is particularly true in stands where the merchantable trees are all comparatively old. This point should be carefully considered in thinning groups.

COMPARISONS OF LOSSES

The ultimate success of marking is dependent upon both potential growth rates, as discussed above, and survival of the growing stock.

On the plots from which the data in Table 4 were taken there were 4,669 living trees, 4 inches in diameter and over, after cutting in 1910.

Between 1910 and 1925, 172 trees died. The distribution by classes of the total trees in 1910 and of the trees which died is shown in number of trees and basal area in Table 4. The fourth and last columns of figures show the relative liability of the different classes to loss, or the ratio of occurrence in the losses to occurrence in the stand.

On a numerical basis it is evident that the class 1 trees are the lowest risk. They are represented in the losses only about one-seventh as frequently as in the total stand. The liability to loss is from five to fifteen times greater for the other classes. Class 7 has the highest risk factor, followed by classes 4, 2, 6, 5, and 3. It is fortunate for the reserve policy that the class 3 trees have the lowest risk factor of any class except the first.

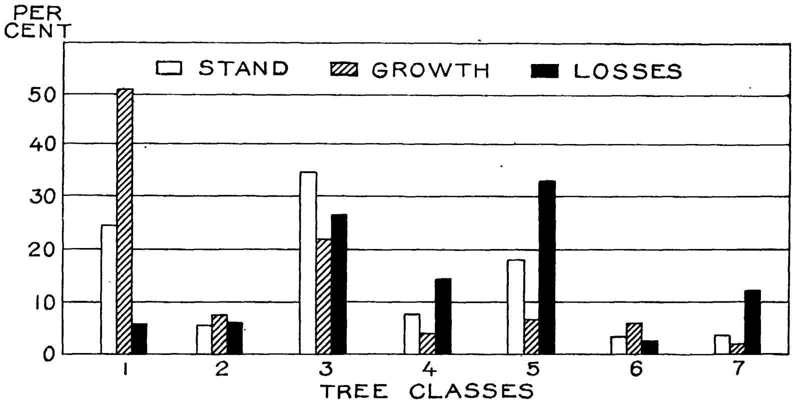

FIG. 3.—Apportionment between the seven tree classes of the total basal area of the stand, the total growth produced between 1910 and 1925, and the total loss in the same period. The data are taken from 4,669 trees totaling 7,855.64 square feet in basal area

TABLE 4.—*Apportionment of stand and mortality in each tree class, 1910–1925, in percentage of number of trees and basal area, with relative liability to loss of the trees in each class* [a]

Tree class	Apportionment in trees			Apportionment in basal area		
	Total stand	Mortality	Ratio mortality to stand [b]	Total stand	Mortality	Ratio mortality to stand [b]
	Per cent	*Per cent*		*Per cent*	*Per cent*	
Class 1	34.0	4.7	0.14	24.9	5.2	0.21
Class 2	8.4	13.4	1.60	5.7	5.6	.98
Class 3	15.4	11.6	.75	35.0	26.7	.76
Class 4	6.6	11.6	1.76	7.8	14.5	1.86
Class 5	5.5	6.4	1.16	19.5	33.6	1.72
Class 6	16.5	23.2	1.41	3.2	2.3	.72
Class 7	13.6	29.1	2.14	3.9	12.1	3.10
Total	100.0	100.0		100.0	100.0	

[a] Based on 4,669 trees having a total basal area in 1910 of 7,855.64 square feet. Mortality was 172 trees, totaling 334.99 square feet in 1910.

[b] Loss ratios, or risk factors, were obtained by dividing the figures in column 3 by those in column 2 and those in column 6 by those in column 5, class by class.

The significance of the loss data is more clearly brought out through basal area comparisons. On this basis the class 1 trees still represent much the lowest risk, followed by classes 6, 3, 2, 5, 4, and 7. The greatest actual losses occurred in classes 3, 4, and 5, partly because the trees in these groups were large and formed a considerable portion of the reserve and partly because of a higher loss rate, especially in classes 4 and 5, as indicated by the high ratios in the last column of Table 4. (See also fig. 3.) If the relative risks were expressed in terms of value exposed to loss rather than basal area, the disparity would be much greater, since classes 3, 4, and 5 produce the highest percentage of upper-grade lumber.

The greatest single cause of mortality was bark beetles (Dendroctonus), which killed 61, or 35 per cent, of the 172 trees and accounted for 50 per cent of the basal-area loss. The distribution of insect losses by tree classes as compared with losses from other causes is given in Table 5.

Only a small part of the loss from insects occurred in the younger tree classes 1, 2, and 6, the greatest portion, nearly half the total, being in class 5. The relative risk of loss from insects in the various classes may be expressed by the ratios in Table 5, derived by dividing the percentage of the total basal-area loss occurring in each class by the percentage of the total basal area of the stand in each class. For comparison, similar ratios for other causes of loss are also shown.

TABLE 5.—*Distribution of losses in basal area from insects and other causes by tree classes, with relative liability to loss of the trees in each class*

Tree class	Insect damage		Other loss	
	Distribution of loss	Ratio mortality to stand	Distribution of loss	Ratio mortality to stand
	Per cent		*Per cent*	
Class 1	3.4	0.14	7.0	0.28
Class 2	5.4	.95	5.8	1.02
Class 3	14.6	.42	38.6	1.10
Class 4	16.2	2.08	12.8	1.64
Class 5	48.7	2.50	18.6	.95
Class 6	1.1	.34	3.5	1.09
Class 7	10.6	2.72	13.7	3.51
Total	100.0		100.0	

The probability of insect loss is greatest in class 7. Such trees appear 2.72 times as frequently in the losses as they do in the stand as a whole. The high factors for classes 4 and 5 are particularly significant because of the high-grade material contained in trees of these types. The above comparisons indicate that only trees of classes 4 and 5 are more subject to losses from beetles than from other causes. For class 5 trees the risk from beetles is more than two and one-half times as great as from other causes. It is worth noting that class 3 trees, which should properly make up the bulk of the better quality of timber reserved, are apparently less liable to damage from insects than from other causes. These relationships are shown graphically in Figure 4.

The above comparisons in basal area show the combined results of relative susceptibility and amount of timber exposed to loss. The selective tendency alone is more strikingly indicated by numerical comparisons, as shown graphically in Figure 4. The small-crowned mature codominants of class 4 are indicated to be the most liable to insect damage.

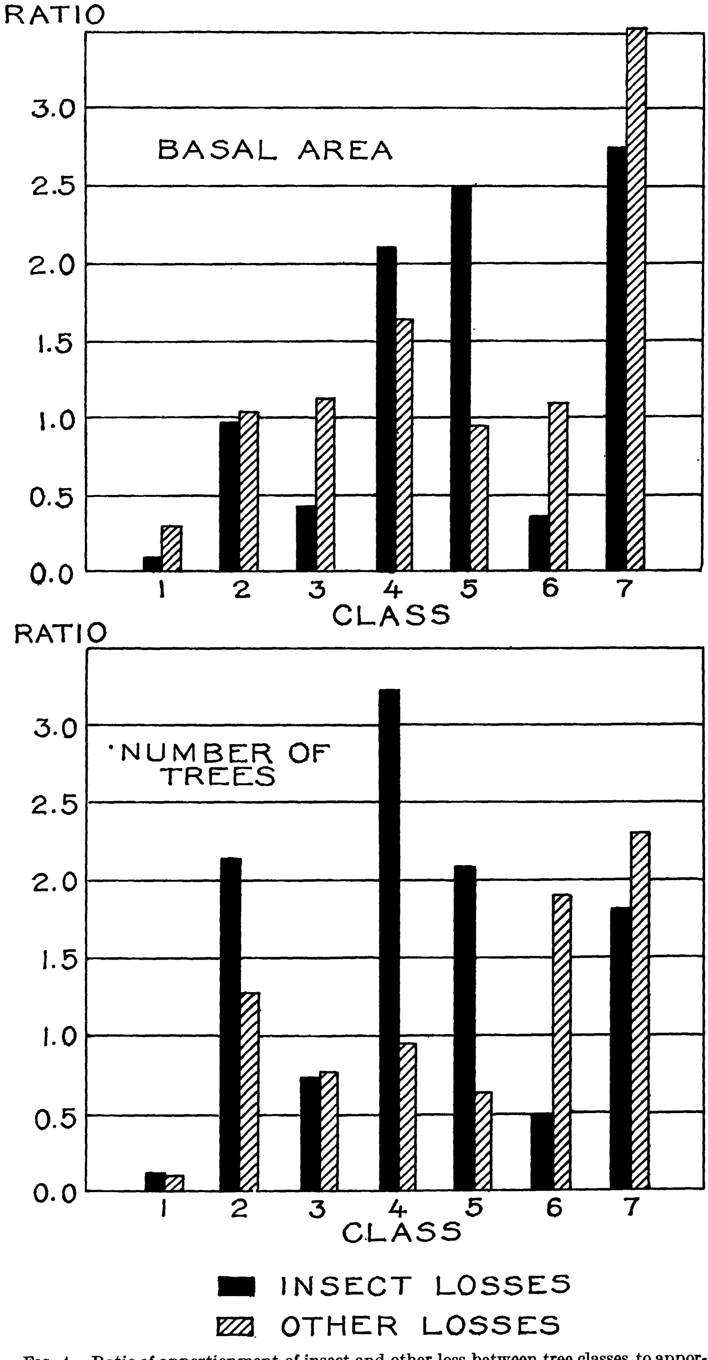

FIG. 4.—Ratio of apportionment of insect and other loss between tree classes to apportionment of stand between classes; in other words, the relative liability to loss of the different classes

The relative susceptibility of various tree types to killing by the western pine beetle, as indicated above, is in close agreement with the carefully controlled experiments by H. L. Person, of the Bureau of Entomology, already referred to. The elimination of susceptible trees in cutting would doubtless lessen endemic insect damage, the most important cause of loss on cut-over areas.

COMPARISONS OF SEED BEARING

The seed-bearing capacity of forest trees has been shown by many investigators to be affected by a large number of environmental phenomena and inherent qualities. In the present study the aim has been to determine only how well the proposed tree classes integrate seed-bearing capacity, and no attempt has been made to record the more fundamental biological influences involved. Even so, the present results are but tentative.

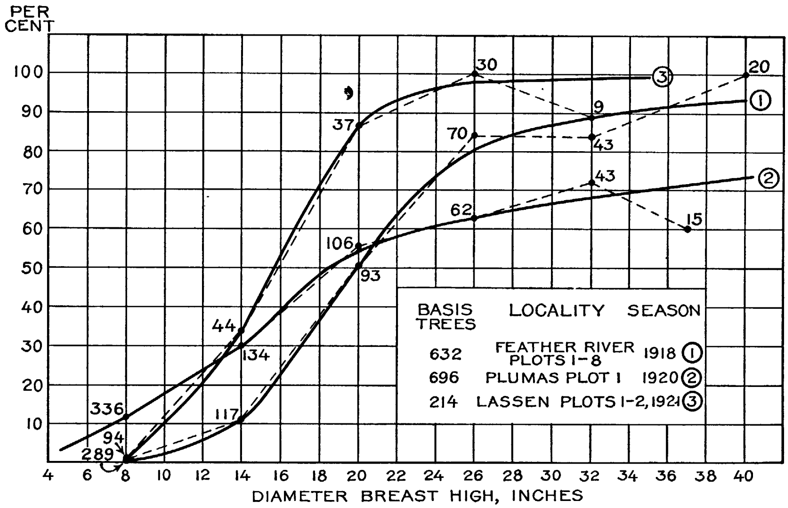

FIG. 5.—Percentage of trees of various diameters bearing cones, taken in three different localities in good average years. Data are for western yellow pine only

The physical difficulties encountered in a quantitative determination of the amount of seed borne are obvious. Unfortunately, too, there have been no really heavy general seed crops since the trees have been under observation, such as would permit comparison of seed bearing by similar tree types under different site conditions, or the consistency of bearing by the same trees from year to year. The data available necessarily limit comparisons to single localities and certain years. There are, however, certain outstanding differences which justify consideration. At present it is impossible to go further than to indicate what types of trees appear to be the best seed bearers. Determination of the exact quantity and quality of seed that is produced and remains undestroyed by insects, rodents, etc., must be left for further study.

Observation indicates that occasionally a potentially good seed bearer sets a heavy crop of fertile cones all of which are destroyed before maturity by cone beetles or rodents. For all species except sugar pine (*Pinus lambertiana*) it has been found impossible to count the immature cones early enough to avoid these losses. In the absence of exact knowledge it is assumed for the present that such damage is not restricted to any particular tree class and that the figures presented are therefore comparable.

Under similar conditions of site, the major factors influencing seed bearing appear to be age, position in the crown canopy, and crown development. Since the size attained is closely correlated with age, crown class, and crown development, it is to be expected that there exists a close relationship between diameter and seed-bearing capacity. This relationship is shown in Figure 5 for three localities in different years.

Below 8 inches a negligible percentage of the trees bore cones. Between 8 and 26 inches the proportion of trees bearing cones increased rapidly. Above 26 inches practically all the trees bore some cones. At 20 inches, the size ordinarily regarded as representing satisfactory seed trees (*13*), from 50 to 90 per cent of the trees bore seed in these years.

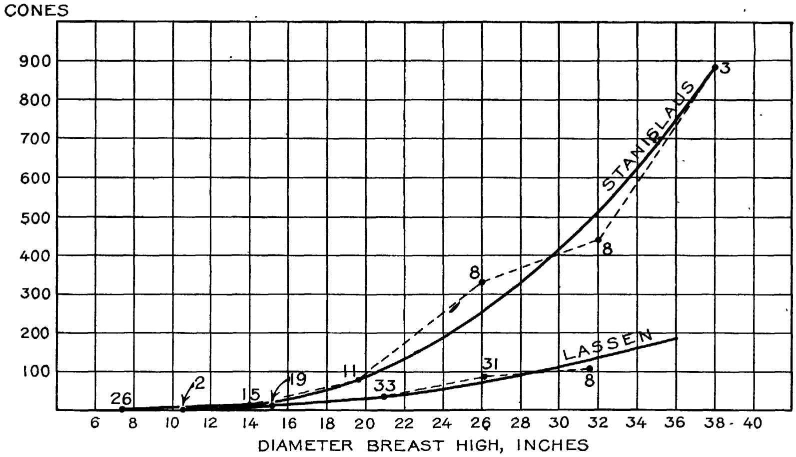

FIG. 6.—Number of cones per tree at various diameters. Count taken on western yellow pine on Lassen plots 1 and 2, and Stanislaus plot 5, 1925

It is well known that for many species there is a fairly definite alternation of seed years and barren years. Thus in the sample plots on the Lassen National Forest, only 62.5 per cent of the trees bore seed in both the seasons of 1921 and 1926. Furthermore, in the seasons of record the seed crops were never exceptional. Were records for a number of years available, covering one or more years of heavy crops, they would doubtless show much higher percentages of trees capable of bearing seed than the chart indicates.

The number of cones borne also varies consistently with diameter, which serves as an indirect integration of age and other factors. The number of cones per tree for two areas is shown in Figure 6 for the year 1926. The difference between the two curves illustrates the great local variation in the seed crop of the same season, the Lassen area being situated 160 miles north of the Stanislaus. These curves indicate that, in years of ordinary seed crops at least, rather large trees are necessary for the production of considerable quantities of seed. Although 50 per cent or more of the 20-inch trees may be capable of bearing seed, the number of cones borne by them is relatively small.

The foregoing discussion indicates that the best seed trees will be found in the tree classes represented by the larger sizes. The summary in Table 6 of typical data from the Feather River group of plots makes this clearer.

The indicated differences are doubtless a result of the combined influences of age, crown development, and position or size. Comparison for a given size class is impossible because, in the nature of things, there is no one size class in which all the tree classes are well represented. It is apparent, however, that seed-bearing trees will most frequently be found among the principal trees of classes 1, 3, 4, and 5, and that classes 2, 6, and 7 provide an insignificant number of seed bearers. This relationship has been well established by a considerable number of investigations elsewhere (*14*, *15*).

TABLE 6.—*Percentage of trees in each class bearing cones and average diameter breast high of each class; eight Feather River plots, 1918*

Tree class	Trees recorded	Trees bearing cones	Average class d. b. h.
	Number	*Per cent*	*Inches*
Class 1	214	22.9	15.0
Class 2	84	14.3	13.5
Class 3	154	55.8	25.7
Class 4	52	40.4	20.4
Class 5	4	100.0	38.8
Class 6	97	1.0	7.3
Class 7	27	11.1	11.4
Total	632	27.9	

As to quantities of seed per tree, the scanty data from present observations and the more ample results of other investigators (*10*) leave little doubt that trees of the types found in classes 2, 6, and 7 bear but few cones. The largest numbers of cones per tree thus far counted were for trees of class 3.

SUMMARY

A tree or thrift-class grouping applicable to selection stands is needed which, unlike the conventional crown-class and other tree classifications for even-aged stands, will be suitable for all-aged mixed forests. On the basis of observations of permanent sample plots over a period of 15 years a tree grouping is proposed comprising seven classes defined by combinations of easily observed factors influencing vigor. The major factors considered are age, degree of dominance, and crown development. Confirmatory indications of relative vigor considered are form of top, color and density of foliage, character of bark, size, etc. Trees should be judged undesirable on the basis of unmerchantability and liability to loss rather than rate of growth.

Marked differences in rates of growth and susceptibility to loss demonstrate that the grouping proposed is a reliable integration of vigor.

Class 1 trees grow at the best rate and have the lowest loss liability factor. They are the least susceptible to insect attacks. They are good seed bearers when of sufficient size. The present value of timber from such trees is comparatively low. They should practically always be retained when sound.

Class 2 trees make fair growth, but are rather liable to loss and are poor seed bearers. They should be marked in preference to the larger class 1 trees when there are sufficient other thrifty trees to make up the reserve, or in thinning groups.

Class 3 trees grow rather slowly, but can be expected to increase in value without great risk of loss. They are good seed bearers. Such trees are desirable for retention as seed trees, or to constitute a moderate reserve of high-quality material for a second cutting in a reasonably short time. The usual tendency is to retain too many trees of this type. However, where sufficient class 1 trees are lacking, where good seed trees are needed, or where a second cutting must be provided for, there should be no hesitancy in leaving class 3 trees. Care should be taken not to include in this class overmature, slow-growing trees. Size varies greatly with site, but only exceptionally will trees of this type be found over 30 inches in diameter.

Classes 4 and 5 trees produce practically no growth even on the best sites. Their liability to loss is high. Their retention involves a large and insecure investment in high-quality timber. They should always be cut, unless there are no other available seed trees.

Classes 6 and 7 trees are usually too small to be merchantable. Class 6 trees grow fairly well and give promise of later development if released. They bear practically no seed. When merchantable they should be cut, unless relief from competition is insured by removal of other trees. Class 7 trees are undesirable from every standpoint and should always be cut if merchantable.

Seed trees should be of classes 1 or 3, and from 20 to 30 inches in diameter.

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