CLASSIFYING FOREST AND OTHER VEGETATION FROM AIR PHOTOGRAPHS

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EDITOR'S NOTE: This is the first phase of a chapter on Forestry for the Manual of Photogrammetry which the Society is having prepared by outstanding leaders in this specialized field of engineering. The second phase by Mr. Wieslander and Mr. Wilson will follow in an another issue of PHOTOGRAMMETRIC ENGINEERING.

INTRODUCTION

SINCE 1937 in connection with a vegetation mapping project,[2] the California Forest and Range Experiment Station has been carrying on studies with the use of air photographs for the purpose of developing improved mapping techniques. Preliminary results of this research were reported in 1939.[3] These and more recent results have now been crystallized in classifications and procedures that are proposed as a basis for future mapping work in the Forest Survey of California and western Nevada.[4] The classifications and procedures, together with proposed map presentation, are described here for their possible value in similar or related surveys elsewhere.

KIND AND EXTENT OF THE VEGETATION BEING CLASSIFIED

The gross area it is proposed to classify from air photographs in California and western Nevada approximates 70 million acres. Of this area about 19 million acres support conifer timber stands; 3 million acres are deforested land, largely shrub-covered; 10 million acres are nontimberland supporting cordwood stands of various oaks and other broadleaved trees as well as piñon pine and juniper; 8 million acres are nontimberland supporting chaparral; and an unestimated acreage supports grass, sagebrush, or subalpine vegetation. As would be expected in a region where elevations range from below sea level to nearly 15,000 feet above and annual precipitation from less than 5 to more than 90 inches, the vegetation is varied and complex, comprising many species.

PURPOSE OF THE CLASSIFICATIONS

The objectives of vegetation classification in California and western Nevada are twofold:

1. To provide maps showing the kind, character, and distribution of the natural vegetation of forest and related lands as a basis for wise management of timber, range, water, recreation, and wildlife resources.

2. To facilitate estimation of the volume of timber and cordwood in the region as part of the Federal Nation-wide forest survey and to localize such estimates by county units.

[1] Maintained by the U. S. Department of Agriculture at Berkeley, Calif., in cooperation with the University of California.

[2] Wieslander, A. E. First steps of the Forest Survey in California. Jour. Forestry 33: 877–884. 1935.

[3] Burks, G. F., and R. C. Wilson. A vegetation inventory from aerial photographs. PHOTOGRAMMETRIC ENGINEERING 5(1): 30–42. Jan.–Mar. 1939.

[4] Wieslander, A. E., H. A. Jensen, R. C. Wilson, and G. F. Burks. Proposed plan for the vegetation type and inventory phases of the Forest Survey in California and western Nevada. 1942. (Unpub. ms.)

Air Photographs and Base Map Requirements

Most of the area covered by air photographs in California and western Nevada, as in the rest of the United States, is by an approximate scale of 1:20,000 or about 3 inches = 1 mile (original negatives are either 7×9 or 9×9 inches in size). To date (July 1942) about 60 percent of the forests and related lands have been flown, most of them by the U. S. Department of Agriculture. This flying was done mainly during summer months of the past 3 or 4 years. The 1:20,000 photo scale is large enough to show a fair amount of detail, and summer-flight photographs are free from long shadows even on rather steep north slopes. In a Nation-wide survey this type of photograph seems to be the best adaptation to the variety of requirements of engineers, agriculturists, foresters, timber cruisers, and range surveyors. Therefore the techniques of forest and vegetation classification described here were developed for use with the 1:20,000 scale photograph and for summer flying, even though in some predominantly forested areas either larger or smaller scales and other flying seasons are probably desirable for economy and amount of forest detail required.

Accurate base maps are necessary for adequate presentation of the classifications; and it is assumed that planimetric or topographic base maps prepared from air photographs will be available. During the past several years, the Division of Engineering of the United States Forest Service in California has been compiling planimetric base maps from air photographs by the radial-line-templet method. These are $7\frac{1}{2}$-minute quadrangle units on a 2-inch = 1-mile scale; they show all the planimetric features of the landscape, including the drainage pattern, landmarks, culture, and section lines. Since a fair amount of vertical control is established at the time of the planimetric survey, the topography may be drawn in later with little additional control when the extra cost is justifiable.

Classification and Techniques

General Basis of Classification

In this scheme the natural vegetation is classified according to prescribed percentages of the ground space covered by component elements individually or in various pattern combinations. Other features such as cultivated, urban, industrial, and barren areas are classified and delineated directly as they appear on the photographs.

Method of Photo-Interpretation

The classifying is done by trained technicians who study pairs of photographs through magnifying stereoscopes. Experience has shown that foresters with some training in engineering are best adapted for this work. Skill in photo interpretation can be acquired only after considerable field experience in checking photographic details. This background of experience and a general knowledge of the region to be mapped are the keys to recognition of vegetation elements and other features on air photographs. Their photographic appearance depends not only on the topographic situation in a region, but also on the season and time of day the photographs were taken. Film or filters, or both, used in the camera, quality and focal length of the lens, techniques of printing and developing, and perhaps most of all, scale of the original negative also affect the appearance of photo details. Therefore it would be very difficult, if not impossible, to define the photographic characteristics of the vegetation or other features to fit all

cases. However, certain characteristics hold true in general for the usual 1:20,000 scale many-purpose photographs. Although these characteristics alone will not always allow positive identification of an element, they seem important enough to mention as illustrative of the kinds of contrasts that must be considered in the interpretation of vegetation on air photographs. The key that follows is intended to give a few of the outstanding contrasts. Symbols shown below are those used to illustrate classification of vegetation (Fig. 4).

Basic Elements and Features and Their Identification

Natural Vegetation

1. Timber trees. All conifer tree species of timber or pulpwood value.

1 2 3 4

Identification: Trees, both timber and cordwood, down to minimum sizes shown in Fig. 1 usually appear more irregular in pattern and darker in tone than other vegetation. Pattern and tone in timber-tree canopy are more regular (suggestive of stippling) and often darker than in cordwood stands. Individual tree crowns are longer and more pointed or tapering, as revealed by shadows. Stereoscopic images of individual crowns are more nearly circular and narrower than images of cordwood trees of comparable heights.

2. Cordwood trees. Hardwoods and montimber conifers such as Digger pine, piñon pine, and juniper.

Identification: Pattern and tone of hardwood canopy are usually irregular, tree crowns blending together so that individual crowns are indistinguishable in dense stands. Individual crowns in open stands are usually broader and have a more irregular spread than timber trees of comparable heights, and the crowns are more definitely rounded or flat on top, as revealed by shadows. Nontimber conifers are sometimes difficult to distinguish from timber conifers and may be included with them pending field checking in areas where there ranges meet. However, these areas are so restricted that the amount of field checking thus required will be small. Stands of dead trees (snag areas), either timber or cordwood, are also designated, and may be identified by their very light tone.

3. Shrubs. Shrubs together with trees of shrub stature below the sizes illustrated in Fig. 1.

Identification: Pattern varying in regularity, with various tones of gray, which depend largely on species composition. Stereoscopic height of shrubs is negligible if apparent at all.

4. Herbs. Herbs, grass, or other herbaceous plants. Meadows are given a separate designation.

Identification: Upland grass has an even light gray tone. Meadows exhibit an even dark gray tone but not usually as dark as open water.

FIG. 1. Minimum sizes of timber trees (A) and cordwood trees (B) visible in 1:20,000 scale air photograph. Below these sizes they are indistinguishable from shrubs.

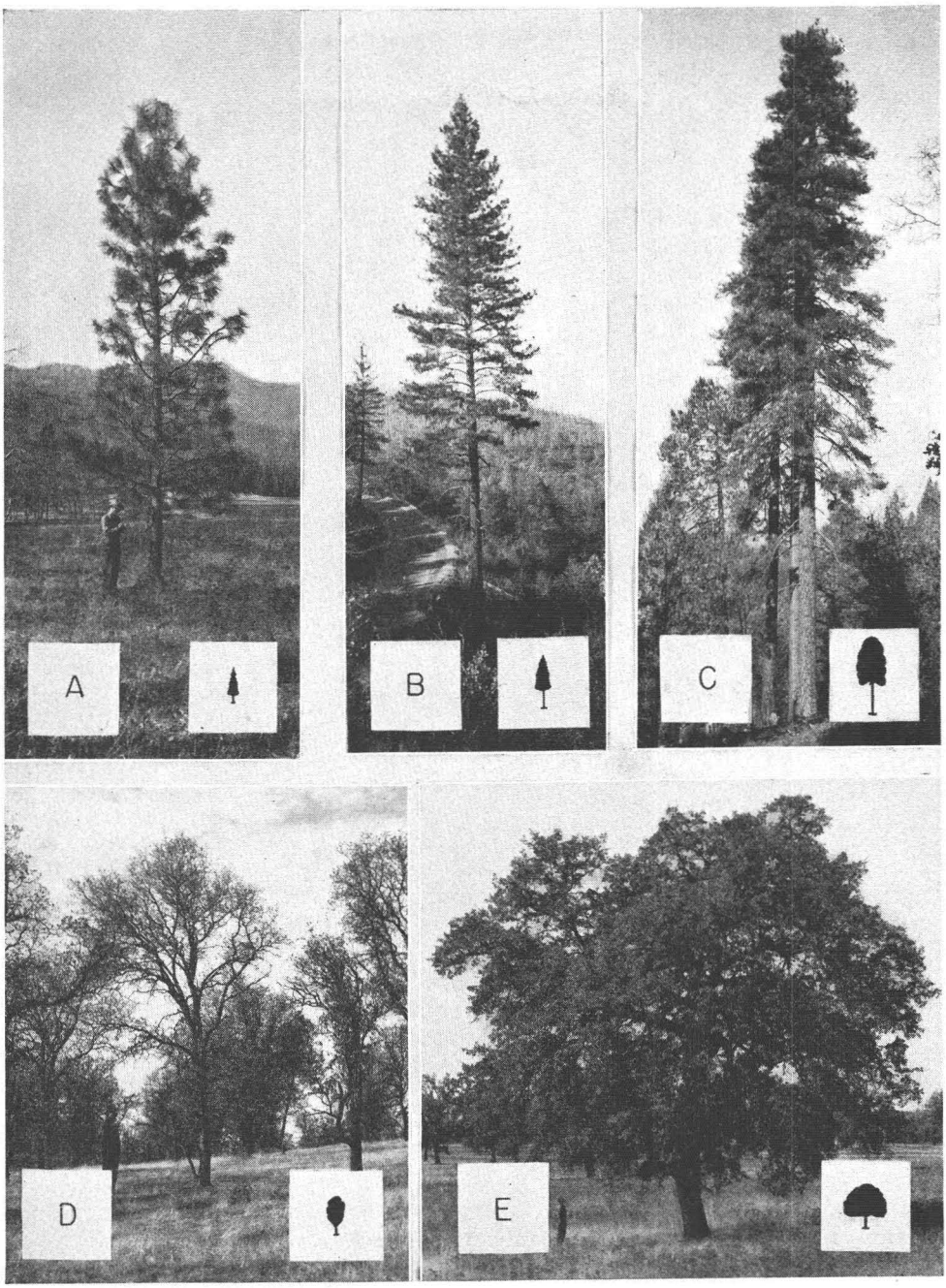


FIG. 2. Age-class elements visible in 1:20,000 scale air photographs: (A) Small immature timber tree—under sawlog size; (B) Large immature timber tree—sawlog size; (C) Mature timber tree; (D) Immature cordwood tree; (E) Mature cordwood tree.

Age-Class Elements (Illustrated in Fig. 2)

1. Small immature timber trees.

Identification: Crowns are very narrow and distinctly circular in horizontal outline, darker than cordwoods of the same height. Trees are short, and crown shadows are pointed.

2. Large immature timber trees.

Identification: Crowns are narrow to intermediate in width, circular in horizontal outline, and intermediate in height. Crown shadows taper to a point or are slightly rounded.

3. Mature timber trees.

Identification: Crowns are wide and circular to slightly irregular in horizontal outline. These trees form the tallest tree group. Crown shadows are rounded to flat on top.

4. Immature cordwood trees.

Identification: Crowns are narrow to intermediate in width. Images on 1:20,000 scale photo usually are 0.1–0.25 mm. wide (denoting crown spread of about 10–20 feet), and are irregularly rounded in horizontal outline. Trees are short. Crown shadows are rounded or flat on top.

5. Mature cordwood trees.

Identification: Crowns are widest in these trees. Images on 1:20,000 scale photo usually are 0.4–0.7 mm. wide (denoting crown spread of about 30–50 feet), and are irregularly rounded. Trees are intermediate in height with flat-topped crown shadows.

Thus the factors of most aid in differentiating the above age classes are relative tree heights and tree-crown characters. Since magnified stereoscopic images or crown shadows, or both, provide the criteria for recognition of these factors, the extent to which these criteria may be used depends largely on stand densities, topographic situation, and season or time of photography.

Other Features

1. Barren. Apparently devoid of vegetation; separate designations are given to barren ground and rock.

Identifications: rock shows very light gray to white tone; barren ground slightly more irregular in pattern and slightly grayer in tone than grass.

2. Open water.

Identification: usually very dark to inky black tone except where sunlight reflected into the lens gives a white or silvery tone. Muddy water and shoals also appear lighter in tone. Despite these variations in tone, bodies of water can scarcely be confused with other features because of contrast in slope and appearance of the shore line.

3. Cultivated land. Segregated by major type of use. Areas no longer cultivated are designated as abandoned, although classified according to present cover.

Identification obvious from regularity of various cultivated patterns.

4. Urban and industrial areas. Identification obvious.

5. Plantations of trees.

Identification: Uniformity in spacing and size of trees.

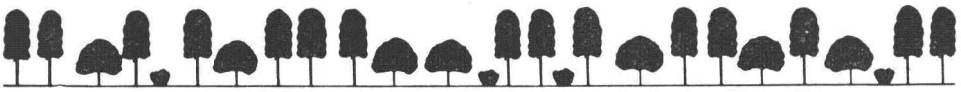
The vegetation elements given above and the barren areas are the basis for the following classifications. The percentages used in defining them, although checked in borderline cases by micrometer measurements along line samples drawn on the photographs, are estimated and applied as approximate guides instead of precise divisions.

The Classifications

Vegetation Classes

Applied to all lands except cultivated, urban, and industrial areas and apparently barren areas, which are classified and delineated directly as they appear on the photographs.

1. Areas essentially composed of a single vegetation element.



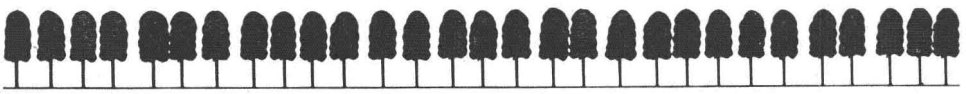
2. Areas in which two or more vegetation elements are significant.

Ordinarily a vegetation element is not considered significant and is not designated in the classification unless it occupies 20 per cent or more of the ground space or forms 20 per cent or more of the total vegetation cover. However,

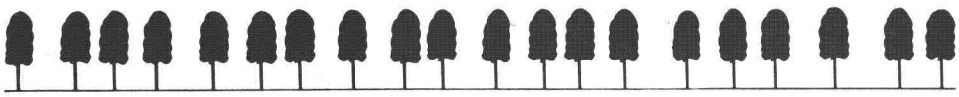
timber trees, cordwood trees where they are the only trees present, and shrubs in treeless areas are considered and designated where they occupy 5 per cent or more of the ground space. The barren element is designated in both vegetation classes 1 and 2 where it occupies 20 per cent or more of the ground space.

Density Classes

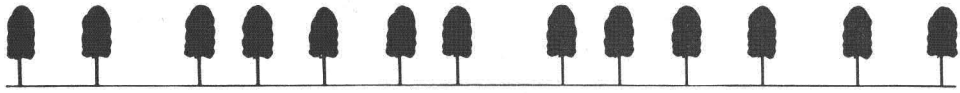
Applied to the combined tree and shrub cover on all lands, to the timber trees alone, and to the cordwood trees on nontimber sites.



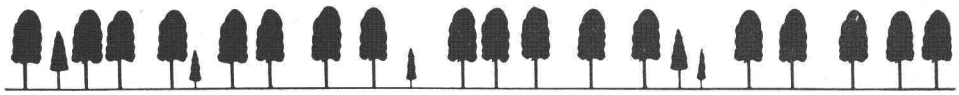
1. Dense. Stands in which the crowns cover 80 per cent or more of the ground space.



2. Semidense. Stands in which the crowns cover from 50 to 80 per cent of the ground space.



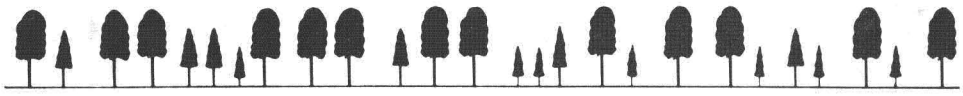
3. Open. Stands in which the crowns cover from 20 to 50 per cent of the ground space.



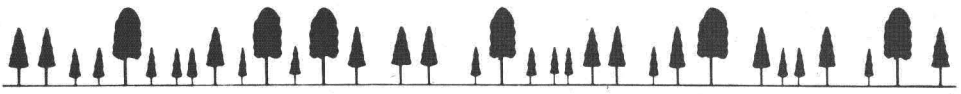
4. Very open. Stands in which the crowns cover from 5 to 20 per cent of the ground space.

Age-structure Classes

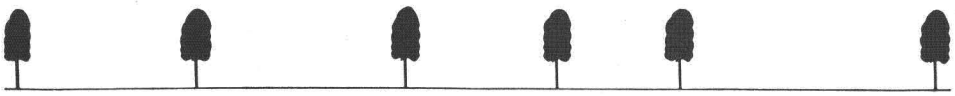
Applied to timber trees on timber sites and to cordwood trees on nontimber sites. In timber stands the age-class elements present, as well as the composite structure, are recorded as illustrated in Fig. 4C.



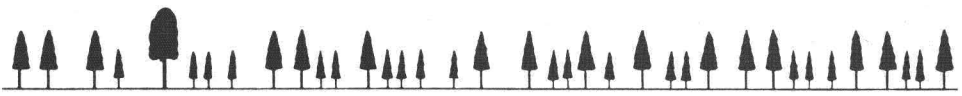
1. Old growth. Stands in which mature trees form 80 per cent or more of the crown space.



2. Old growth—young growth. Stands in which mature trees form from 50 to 80 per cent of the crown space.



3. Young growth—old growth. Stands in which mature trees form from 20 to 50 per cent of the crown space.



4. Young growth. Stands in which mature trees form less than 20 per cent of the crown space. Stands in which the percentage of mature trees is between 5 and 20 are indicated by a special symbol.

Method of Recording

The delineation and designation of these classifications are made on the photographs, as illustrated in Fig. 3. Where two or more vegetation or age-class elements occur in a single classification, the symbols are listed in order of the relative area occupied by each element. Although the entire photograph in Fig.

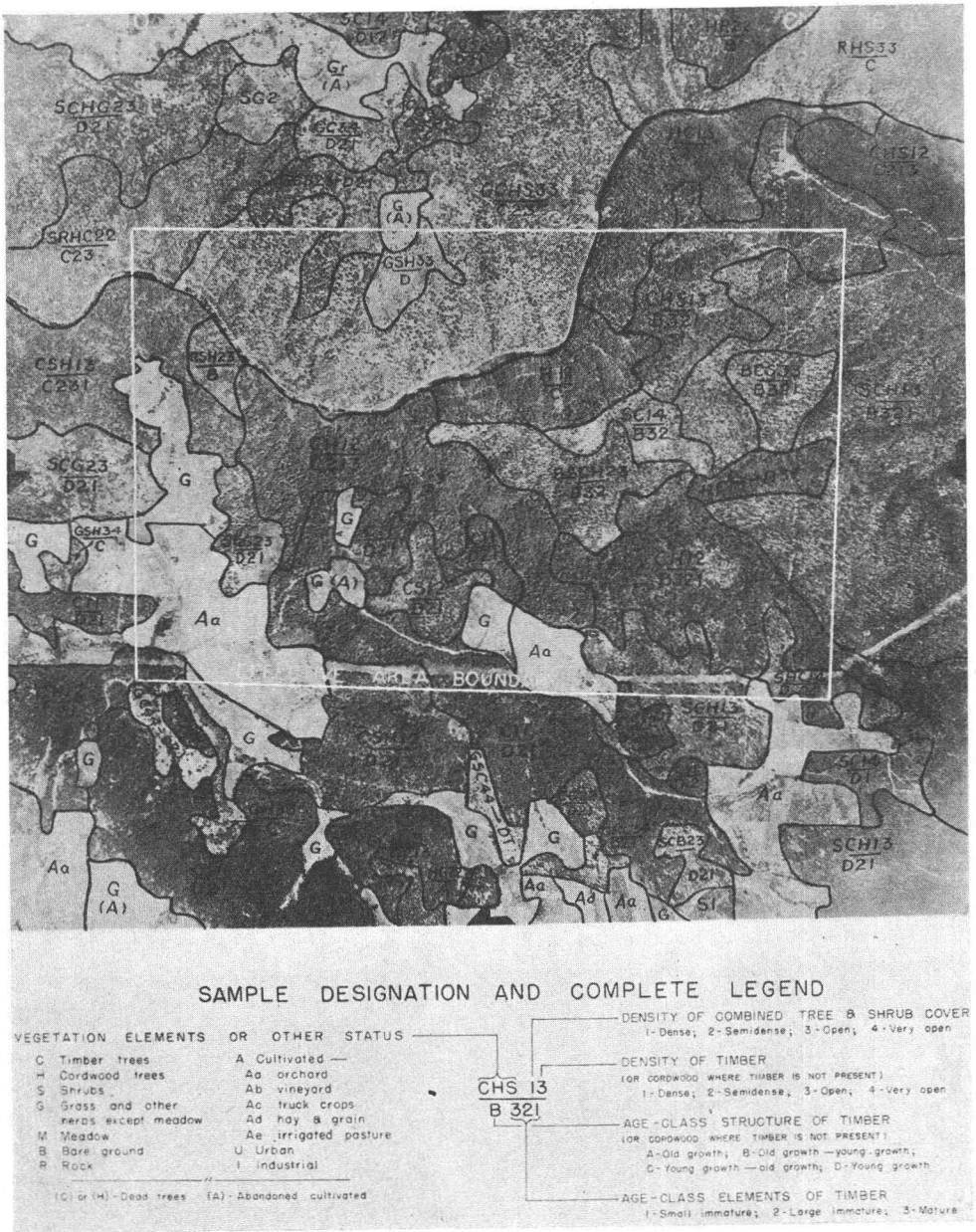


FIG. 3. Example of classified air photograph showing kind of information obtained by office study under magnifying stereoscope. Note effective area boundary referred to above.

3 has been classified in order to illustrate a wider range of conditions, only the central portion of the photograph within the effective area boundary (the same portion used in constructing the base map) would be classified in actual practice. Classifications from the central portions can be transferred to the base map by means of a reflecting projection machine with the least correction for relief displacement and for tilt distortion and so with greatest accuracy, speed, and ease.

Map Presentation

The classifications illustrated in Fig. 3 form the basis for four series of maps, sample profile sections of each being shown in Fig. 4. All the information indicated in the profile samples is shown on the maps by appropriate symbol. These maps are prepared on a scale of 2 inches = 1 mile, and it is planned to issue them as $7\frac{1}{2}$-minute quadrangles in the form of blue-line prints. There follows a brief discussion of each map and of the techniques involved in the supplementary field work required for two of the maps.

Vegetation Classes and Densities

The maps of this series show vegetation classes for all lands according to composition by vegetation elements and densities of tree and shrub cover. This information is obtained entirely from office study of the air photographs. These maps should be more useful for some purposes than the maps showing species composition heretofore prepared by ground work alone. Their utility may be enhanced by coloring in various ways according to the use in mind. For example, if a vegetation map is desired for general purposes the vegetation can be grouped by color legend into the broad classes of timber, cordwood, brush, and grassland, shown in Fig. 4A. On the other hand, if the map is to be used for planning action programs in fire and flood control, or to emphasize concealment or maneuverability values for military purposes, or for estimating the amount of tree and shrub cover to be removed in clearing rights-of-way for roads or power lines, color legends would accentuate the trees and shrubs and their density, shown in Fig. 4A.

Vegetation Types by Species Composition

These maps show vegetation types and their composition by dominant species as indicated in Fig. 4B. For general purposes these maps can be colored to show types such as grass, chaparral, and pine, and for more specific uses to show the occurrence of a single species of tree or shrub that assumes importance because of economic value or scientific interest.

The preparation of this series of maps entails supplementary field and office work as follows:

(a) The air photographs showing vegetation classes and densities are taken into the field for further classification of the vegetation according to natural plant associations. In this classification three kinds of associations, (1) pure, (2) simple mixed, and (3) mosaic mixed stands, as illustrated in Fig. 4B, are recognized and delineated on an overlay of transparent cellulose acetate. Only species exposed to the sky are considered. The first kind of associations comprises those in which a single species forms more than 80 per cent of the cover; the second, those that are wholly arborescent, shrubby, or herbaceous and that are made up of two or more species, each occurring to the extent of 20 per cent or more; and the third, those that are neither distinctly arborescent, shrubby, nor herbaceous but mosaics of two or more of those elements. A pure stand is designated by the single important dominant. In a simple mixed stand each

dominant forming 20 per cent or more of the stand is designated, the dominants being listed insofar as practicable in the order of relative abundance, and in a mosaic mixed stand the dominants designated are those that form 20 per cent or more of each class of vegetation. For example, in a timber-shrub formation each timber species forming 20 per cent or more of the shrub cover is designated as a dominant.

The delineation of these plant associations may or may not require sub-

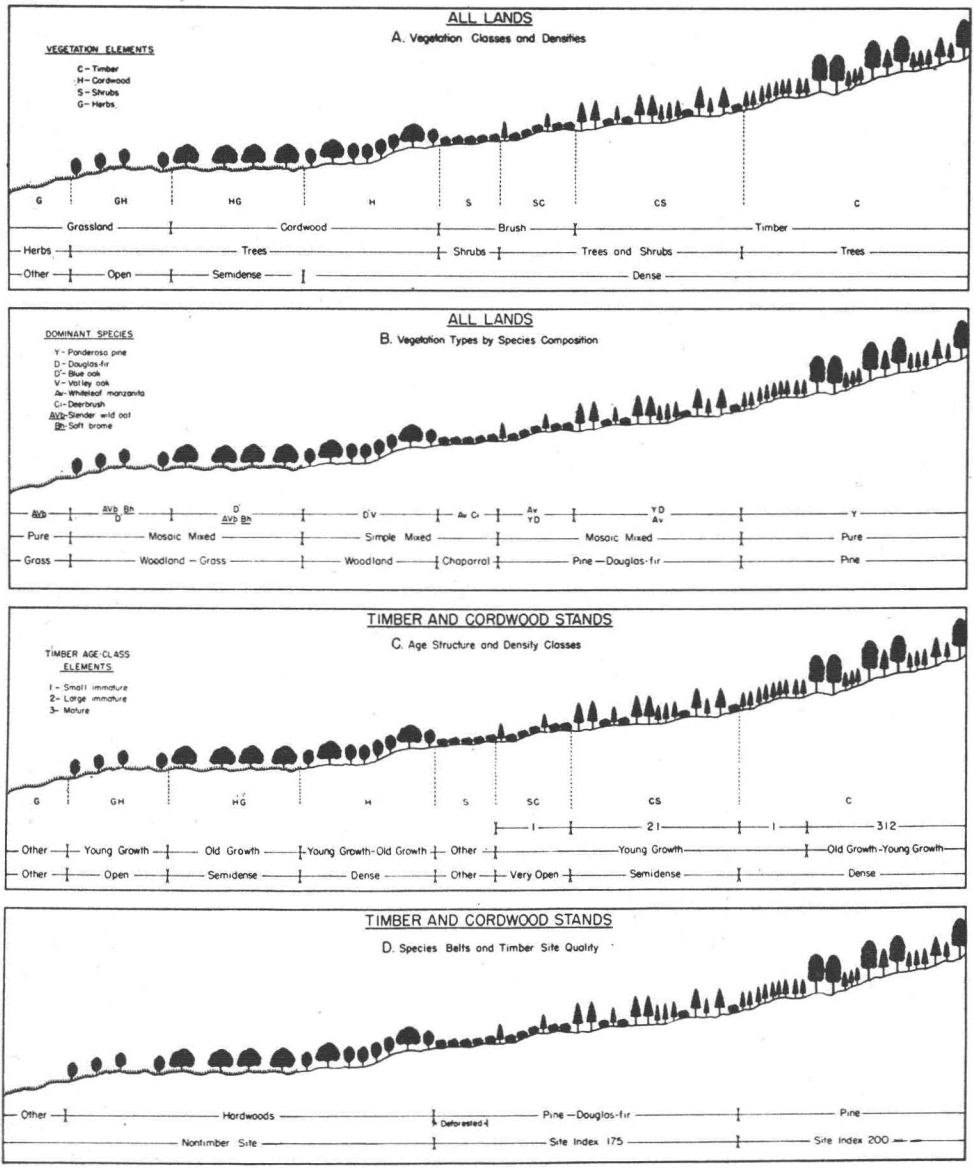


FIG. 4. Profile samples illustrating the kinds of maps that can be prepared for a given area. Information presented in maps A and C is obtained from office study of air photographs. That in B and D requires supplementary field work.

division of the vegetation classes that have been determined by office study of the photographs. For example, ground examination may reveal that one timber area includes only ponderosa pine and therefore requires no subdivision. Another timber area may be composed of ponderosa pine and white fir occurring in three distinct plant associations—pure pine, pure fir, and mixed pine and fir—and thus require subdivision. Delineations such as these are often facilitated by further study of the photographs under a portable field stereoscope. Although the dominants of associations are usually directly observable, their determination will frequently need to be verified by sample plots. In herbaceous formations however, segregation beyond that of marsh, meadow, grass, and bushy herb associations is not attempted, and the determination of dominants when shown is made from sample plots that may or may not typify the entire association outlined. The sample plots also provide information for the proper description of the various plant associations—details of species composition, size of trees and shrubs, and depth of leaf litter.

Age Structure and Density Classes

In this series of maps only areas supporting timber and cordwood stands are classified. These maps show for timbered areas (1) composition by vegetation elements, (2) timber-tree composition according to age classes present, (3) age-structure classes, and (4) stand density of timber trees; for nontimbered areas supporting cordwood stands (1) composition by vegetation elements, (2) age-structure classes, and (3) stand density of cordwood trees. All this information is obtained from office study of the air photographs. The maps may be colored to emphasize either stand density or age-structure classes. The classifications they contain were designed primarily to facilitate and improve the quality of the timber and cordwood volume estimate to be obtained by a sampling system in the Nation-wide forest survey. The maps of this series however will be useful to both public and private owners of timberland not only as an aid in timber cruising and evaluation but also in many phases of forest management.

Species Belts and Timber Site Quality

The maps of this series show species belts and site-index classes for all timber sites, and species belts of cordwood stands on nontimber sites. A color legend may be superimposed to accentuate either species belts or site index classes. Since species belts are derived directly from the map showing vegetation types by species composition, the data for site-index classes are obtained in connection with the field work required for that map.

The species belts segregate timber stands and cordwood stands according to important species groups. Both existing stands and deforested areas are included in species belts of timber, existing stands being classified by key species forming 20 per cent or more of the crown space, and deforested areas being classified by remnant trees, indicator plants, or the adjacent stands and their topographic relationships.

The site-index classes, which grade timberland according to relative capacity for growing timber crops, are based on the age-height relationship of average dominant trees expressed in terms of height attained (in 25-foot classes) at 300 years. In general they coincide with broad climatic belts except where soil or other habitat factors are markedly different from those typical of the locality. The delineation of these classes requires the following steps:

(a) In the field, selection of suitable dominant trees spaced not less than two to a 36-square-mile township and measurement of their height, their location

being referenced by number on the air photograph. Ages are then determined by annual-ring counts of cores extracted from these trees, and site-index values are obtained by reference to age-height curves.

(b) In the field, delineation on air photographs of the boundaries of site-index classes that are clearly evident on the ground, such as those caused by soil differences or by depressed height in windswept areas.

(c) In the office, determination of the boundaries between site-index classes that are not visible on the ground, such as those caused by gradual climatic change with change in elevation. Rainfall and other climatic data are used as guides in locating these boundaries.

Other Use of Classifications

The age structure and density classification of timber and cordwood stands have a use for forest-survey purposes in addition to the map presentation described above. Before the completion of a long-time mapping program, reliable area tables of the timber and cordwood classification illustrated in Fig. 4C can be quickly obtained for watersheds, counties, or other desired units by office line sampling of the air photographs. Then by applying to these classifications average stand per acre figures procured through a system of ground line plot sampling, an inventory of the kind, quality, and volume of the timber is obtained. This use of the classifications and the techniques involved will be discussed in a subsequent article.