

A Reconnaissance Method for Forest Site Classification

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Silviculturists and forest ecologists have evolved many approaches to forest community or site classification for management purposes. Some emphasize vegetation, and others environment. Unfortunately, almost all of the techniques we are familiar with are time-consuming, involving detailed plot studies. In view of the immediate need for information on the large forest areas still unstudied in the western United States, we thought it desirable to develop a classification technique based on quick reconnaissance methods. A rapid technique makes it possible to visit a greater number of stands, thereby sampling both a greater range of variability in a local area and a larger geographic area in less time. The larger number of reconnaissance plots substitutes for fewer detailed plots. Environmental factors amenable to rapid field determination need to be recorded with estimates of vegetative features because of their potential importance in classification and forestry practice. However, the many data accumulated in a rapid survey necessitates the assistance of computers in data analysis.

The reconnaissance approach to forest site classification which we developed and utilized is the subject of this article. The field and analytical methods selected are listed and discussed, using our work in the temperate and subalpine forests of the Oregon Cascade Range, northwestern United States, to exemplify their

application. None of the elements of the approach are new, but the way in which they are combined is new, especially in the joint use of subjective judgement and of more objective computer methods (similarity and gradient analysis) in the analysis and preparation of the final classification. We recognize, however, that the complete and final characterization of the classification units may in some cases require the establishment and sampling of more detailed analytic plots.

The general approach should prove useful in other temperate and subalpine regions. However, the selection of characters recorded and used in the analysis will undoubtedly vary with the natural features of each new study area, the special purposes of the classification, and the preferences and talents of the scientific team carrying out the study. In collaboration with Drs. M. MATSUI and M. MAEDA of the Japanese Government Forest Experiment Station, one of the authors (Dr. JERRY F. FRANKLIN) is presently attempting to adapt and utilize the scheme in classifying the subalpine forests of central Honshu, Japan, for forest management purposes.

Study area

In order to fully understand the following discussion of the reconnaissance method, some knowledge of the area in which it was developed is desirable. This was the H. J. ANDREWS Experimental Forest, a 6,000 ha tract of temperate and subalpine coniferous forest located on the western slopes of the Cascade Range in central Oregon (approximately 44° north

* For computer processing, it was convenient to code abundance data using a scale from 0 (very rare) to 9 (very abundant). Recording data in the field using this scale, or whatever coded scale is actually to be used, avoids the necessity of converting the data from one system to the other prior to card punching, as we had to do.

latitude, 122° 15' west longitude). A classification of the forest communities and sites was needed to stratify areas for ecological and management research.

Elevations of the mature, steep mountain topography range from about 500 to 1,600 m. Geology is entirely volcanic, composed mostly of Oligocene and Miocene andesites, tuffs and breccias, and basalts (ROTHACHER, DYRNESS, and FREDRIKSEN 1967). Soils are generally moderately deep and fine-textured, except on very steep slopes and at highest elevations, where soils are developed in deposits of volcanic ash. In temperate forest, zonal soils are Reddish-Brown and Yellowish-Brown Lateritics and in the subalpine Brown Podzolics are common. The maritime climate is wet and mild, with a total precipitation of 2,300 mm or more. However, most precipitation comes during the winter, and summers (June through September) are quite dry (about 180 mm).

The natural forest vegetation of the study area can be divided into the *Tsuga heterophylla* (temperate) and *Abies amabilis* (subalpine) Zones (FRANKLIN and DYRNESS 1969). The *Tsuga heterophylla* zone extends from about 500 to 1,050 m elevation. These forests are dominated by *Pseudotsuga menziesii*, *Tsuga heterophylla*, and *Thuja plicata*, with *T. heterophylla* the major climax species. Because of the dry summers, the composition and productivity of forest communities varies greatly along a moisture gradient from dry to moist sites.

The *Abies amabilis* Zone extends from about 1,050 to 1,600 m and is dominated by *Abies amabilis*, *Abies procera*, *Tsuga heterophylla* (lower part), *Tsuga mertensiana* (upper part), and *Pseudotsuga menziesii* (lower part). *Abies amabilis* is the major climax species. A moisture gradient is not as strongly developed in this Zone, but depth and duration of winter snow-pack (averaging from 1 to 3 m) exert a major influence on community composition and productivity.

Most forests are one of two general age classes — either 125 or 450 years — as a result of the wildfire history in the study area. The old-growth

forests (450 years) are dominated by trees averaging 120 to 140 cm D.B.H. and 45 to 75 m in height and contain timber volumes averaging 350 to 750 m³/ha. Old-growth forests have a distinctly uneven-aged structure, with an overstory dominated by long-lived seral species (e.g., *Pseudotsuga*) and lower stories of more tolerant species (e.g., *Tsuga*). The so-called "second-growth" forests, 125 years old, are of natural origin following wildfire and even-aged in structure. Typically, they are dominated by *Pseudotsuga* (temperate) or *Abies procera* (subalpine) 60 to 80 cm D.B.H. and 40 to 60 m tall.

Field methods

SELECTION OF PLOTS

The objective in our reconnaissance survey was to sample the complete range of natural forest communities and sites. Transects were run along all major roads and trails within the experimental forest. Large tracts lacking such access were sampled by crosscountry transects which usually ran from ridgetop to valley bottom. Care was taken to insure that all elevations, slopes, aspects, and soil types were included in the samples in approximate proportion to their relative importance in the area.

Selection of locations or stands for sampling along the transects was determined partially by spacing (systematic samples) and partially by obvious changes in forest or site conditions (subjective samples). Systematic sampling was most important along portions of transects where changes in forest conditions were subtle. It insured that even slight variations in communities were included and adequately sampled. Obvious changes in forest communities (age, composition, productivity) or sites (degree of slope, exposure, change in soil type) were criteria for subjective location of plots. If conditions changed radically, plots were often taken at very short intervals, with some as little as 50 to 100 m apart.

The sole requirement for a suitable stand for sampling was that it be relatively homogeneous over a large enough area for both the sample plot and a buffer area (0.5 ha was generally consider-

COLLECTION OF DATA

method. Our objective was to collect a maximum number of data needed to develop a community and site classification in a minimum amount of time. For this reason, exact location of plot boundaries or measurement of vegetative or environmental features was not practiced. Most of the data recorded were based on ocular estimation. Furthermore, the data, to a considerable extent, reflected local conditions and personal preferences. The data we collected are discussed below (see also fig. 1); we felt they were suitable, given our objectives and local

Figure 1. — Example of the form used in recording reconnaissance data during the H.J. Andrews Experimental Forest study.

conditions. Each plot generally required 30 minutes to one hour for completion, with an average of 8 completed plots per work day for a two-man team (soil scientist and plant ecologist familiar with the local flora).

We have used a circular plot approximately 15 to 20 m in diameter. This size was generally large enough to include most of the variation in stand structure and composition we encountered, yet small enough to be thoroughly examined and allow easy estimation of plant coverage and abundance. In practice, the boundaries of the plot tended to be somewhat larger when appraising tree coverage and abundance and somewhat smaller when estimating coverage and abundance of herbs and mosses.

ENVIRONMENTAL DATA

The major environmental data collected were (Fig. 1): (1) a brief description of the soil profile including Soil series; thickness, depth, color, stoniness, structure, and texture of the horizons; and estimates of effective rooting depth and drainage condition; (2) soil parent material; (3) elevation, slope degree, and exposure; and (4) landform (e.g., ridgetop, middle one-third of smooth or uneven sideslope, etc.). The soil description was based on a pit 0.7 to 1.3 m deep placed near the center of the plot.

VEGETATION DATA

The major vegetation data collected were the abundance and coverage of each plant species present on the plot. Slightly different approaches were used for the tree and the understory species. Abundance and coverage were recorded separately for reproduction and mature size classes of each tree species. This was done to distinguish seral species (which have low reproductive vigor) from the climax species which is very important in construction of the eventual classification. Abundance classes ranged from 1 (abundant) to 4 (rare), * and coverage was estimated to the nearest 5 percent.

Coverage and abundance were estimated for each understory shrub, herb, and moss species. It could also be done, with some adjustment of criterion, for lianas (which were absent in our study area) and epiphytes. Coverage was estimated to the nearest percent up to 10 percent and to the nearest 5 percent thereafter. Our abundance classes were, in fact, frequency classes with Class 1 = 0 to 5 percent frequency, 2 = 5 to 25 percent, up to 6 = 95 to 100 percent. This estimate of frequency was based on the probable frequency percent for each species using systematically placed 2 x 5 dm canopy coverage plots of the type developed by DAUBENMIRE (1959). Those not experienced in the use of such plots should probably use a simple abundance scale. Originally, we recorded data only on coverage, but felt this was insufficient since many important indicator herbs can have low coverages but be relatively abundant in the stand.

Other vegetation data collected were (1) forest canopy density, (2) forest age, and (3) site quality. Canopy density was recorded on a scale from 1 (very dense) to 4 (very open). Meaningful recording of forest age in our study area was very easy, since most stands were either old-growth (450-year) or second-growth (125-year). Exact age determinations through increment borings were not needed. Eventually, 5 classes of forest age and structure were used in coding the data: Old-growth, old-growth with dense understory of poles, second-growth, second-growth with scattered old trees, and "mature" forest (200 to 300 years old), which was sparsely represented in the study area. Site quality, based on tree height (either estimated or measured) in relation to age, was used as a measure of productivity.

Analysis of data

Classically, the analysis of reconnaissance data has been a laborious process of subjective comparison of individual stands and the gradual evolution of community types composed of stands most similar in vegetative and environmental features. Exclusive use of such a system is nearly impossible when dealing with large numbers of samples, however. We had 300 when

the survey was completed. Furthermore, the bulk of the stands were moderate in environmental conditions, rather than extreme in moisture or temperature conditions or both. Differences in composition and coverage of the understory between such stands are subtle and may be difficult to identify. Species with broad ecologic amplitudes dominated and high fidelity species were scarce, occurring mostly on very wet, dry, or cold sites.

Consequently, we decided to conduct an analysis of the data which combined our knowledge and intuition with the computer's capabilities for nearly instantaneous comparison

(similarity analysis) of stand data and ordination of the stands based on their similarities. The scheme we used is outlined in figure 2.

PREPARING COMPUTER CARD DECK

The first job in analyzing the data is to punch cards for computer analysis. Each qualitative and quantitative characteristic present in one or more stands and which you may want to use in the analysis is assigned certain computer card spaces in a constant sequence. We identified 17 environmental and general vegetative characteristics which we thought might be useful in developing or evaluating the classification or in editing the total deck of stand data into smaller subsets for analysis. These were: Plot location, landform, elevation, slope, aspect, soil series, parent material, effective rooting depth, thickness of A horizon, texture of A horizon, texture of B horizon, profile stoniness, soil drainage, major climax species, minor climax species, forest age class, canopy density, and site quality. Some of these data could be used directly as recorded (e.g., slope degree or elevation in hundreds of feet), but most were converted to a numerical code for punching. Tree species (15) were each assigned six columns --one for reproduction abundance, two for reproduction coverage, one for mature abundance, and two for mature coverage. Understory species (about 100) each had three columns, one for frequency class, and two for coverage. The large number of characteristics necessitated a total of six cards (each has 80 spaces) for each stand. Each of the six cards had to have the plot number and card number for that plot punched in the first four spaces. Note that all stands would have data punched in the spaces for the environmental and general vegetative features (unless an A or B horizon or minor climax species was absent). However, frequency and coverage are punched only for those species present in the stand so that, in many cases, large numbers of spaces assigned to species absent from that particular stand were left unpunched.

COMPUTER PROGRAM

The computer was utilized to analyze both

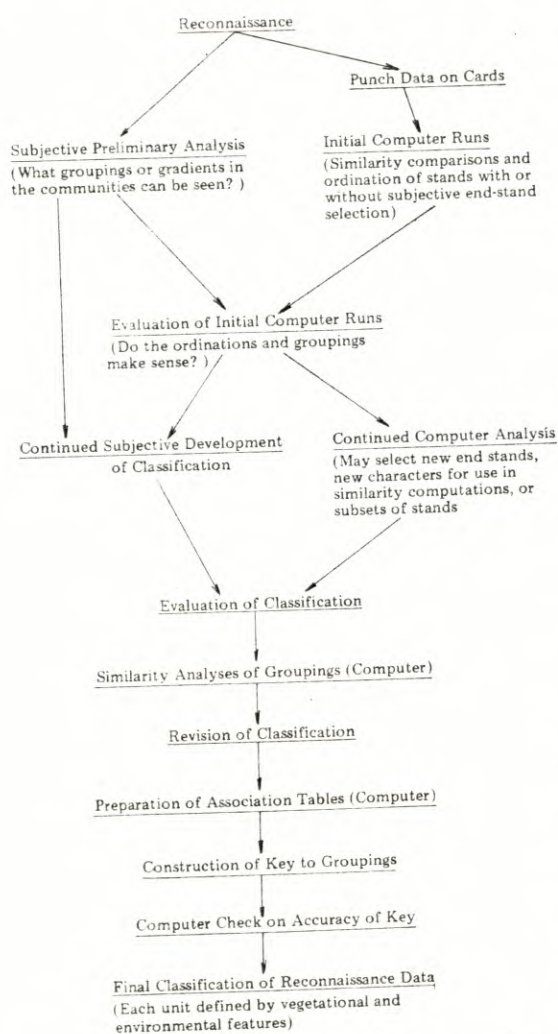


Figure 2. — General scheme followed in concurrent development of site classification using computer and subjective methods.

the entire set and subsets of stands by phytosociologic reference stand ordination (WHITTAKER 1967) using a modified version of program SIMORD, details of which are provided in DICK-PEDDIE and MOIR (1970). This similarity index is similar to the Sorenson K index except that each species compared is weighted by its cover value. The technique is also essentially the same employed by Bray and Curtis (1957) and later elaborated by others as a method of vegetation ordination. Such weighting techniques for similarity comparisons have been reviewed by Whittaker (1967) and McIntosh (1967). Goff (1968) used life form and sizes of different forest species in measuring forest trends.

The formula used for making comparisons between stands is as follows:

$$SIM(I, J) = \frac{1}{n} \sum_{k=1}^n \left(\frac{2 \text{ MIN}(a_{ik}, a_{jk})}{a_{ik} + a_{jk}} \right),$$

for a_{ik} or $a_{jk} \geq 3\%$

where a_{ik} and a_{jk} are coverage, abundance, or importance values for the k th species in stands I and J . The summation is performed only for those n' species satisfying the inequality, although all species in the entire stand set (n) are tested. By this formula stand pairs having no species in common would have zero similarity, whereas identical stands would have a similarity

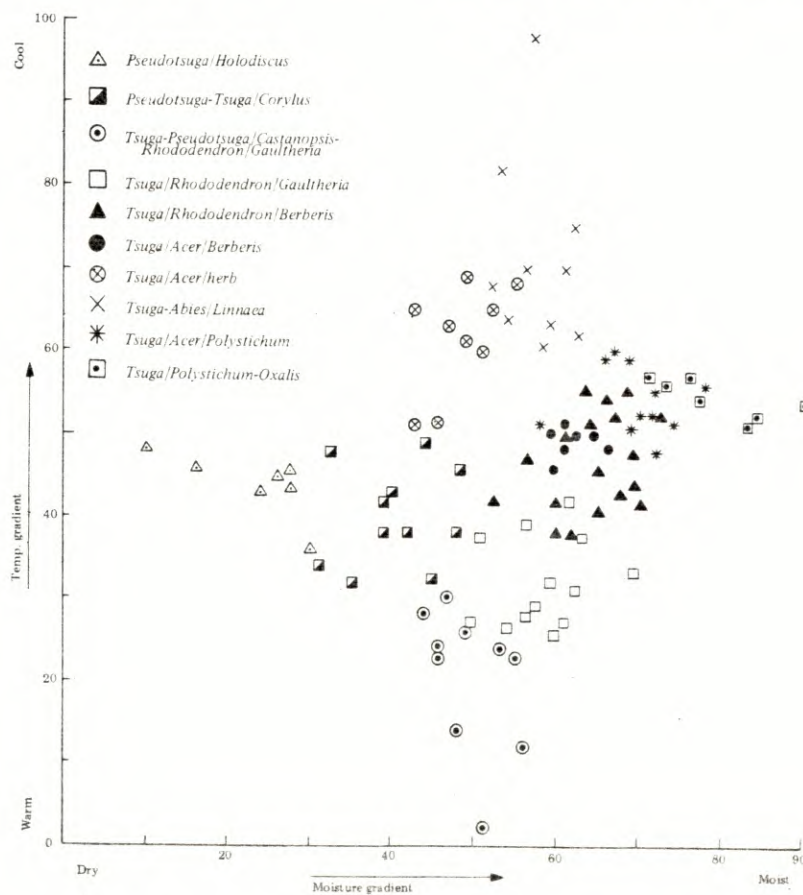


Figure 3. — Two-dimensional ordination of stands within the *Tsuga heterophylla* (lower elevation) zone. Note the pronounced tendency toward clustering into 10 major community types. The x-axis represents a moisture gradient ranging from dry (*Pseudotsuga/Holodiscus*) to wet (*Tsuga/Polystichum-Oxalis*). The y-axis represents a temperature gradient ranging from warm (*Tsuga-Pseudotsuga/Castanopsis-Rhododendron/Gaultheria*) to cool (*Tsuga-Abies/Linnaea*).

value of 100. We have generally used a value of 3 in the inequality with coverage data, which simply means that in one of the two stands being compared, a species must have at least 3-percent coverage before it is included in computation of the similarity between the two stands. Comparison of similarity values obtained using 1 and 3 as the inequality value, with small groups of stands known to be very similar or highly dissimilar in nature, indicated 3 gives better results when using our coverage data.

Following the computation of the similarities, the stands were ordinated in two dimensions (on "x" and "y" axes) using this program. Each axis was arbitrarily defined as being 100 units long. Reference stands for the x ordination axis were chosen on the basis of least similarity. That is, the two stands most unlike each other were placed at opposite ends of this axis. The remaining 298 stands were arranged along the x-axis, based on their similarities with the reference stands. This typically left a large number of the stands in the center of the axis (meaning they were not very similar to either reference stands). From this central stand cluster near the center of x-axis, two more highly dissimilar stands were selected as end points, or reference stands for the y ordination axis. All of the stands were then located within the two-dimensional ordination, based on their relative similarities to the four reference stands. The result of an ordination analysis is shown in figure 3; in this particular computer run, the x-axis appears to represent a moisture gradient and the y-axis a temperature gradient. It is possible, and we often found it advantageous, as pointed out later, to subjectively select end stands for either one or both axes. This can also significantly shorten the amount of computing time.

In fact, it was not possible to use all of the characteristics (approximately 280) in comparisons of the stands. This many characteristics for 300 stands exceeded the storage capacity of the computer being used. Therefore, most of the analyses were made using 50 selected characteristics. These were, for the most part, confined to coverage values for different plant species,

although they could as easily have been abundance or importance values (combining abundance and coverage). The selected sets of characteristics or species varied from time to time, depending upon whether the entire data set (300 stands) or some special subset (e.g., *Abies amabilis* or *Tsuga heterophylla* Zone stands) were being analyzed.

It is difficult to include many of the environmental and general vegetative data in the actual 1 computation of the similarity indices. For example, it is meaningless to include coded data on stand location, exposure, soil series, etc., in the computations, since the numbers have no quantitative meaning, but simply represent an arbitrary coding of qualitative data. It is possible to use some of the quantitative environmental data (soil depth, elevation, etc.) in the similarity computations, but it should be borne in mind that unless the characteristic selected is weighted in some way, it has no more weight than coverage of a single species. We found it more useful to examine correlations between species distributions (ordinations) and the various environmental factors after each computer run. Also, general vegetative characters, such as climax species, were frequently valuable in having the computer select subsets for analysis from the total stand deck.

It should be noted that there are many opportunities in using this program to introduce personal judgements, intuition, and knowledge. Hence, the computer functions as a servant for the scientist, allowing him to test various hypotheses and alternatives using large data sets, and not as a completely logical but biologically ignorant master. Such intuitive judgements can be introduced in: (1) selection of the characteristics to be used in computing the similarity indices (where it is either impossible or undesirable to use them all); (2) weighting of characteristics deemed highly important by using them more than once or using a weighting factor; (3) selection of the value for the inequality in the formula; (4) selection of reference stands for the ordinations; and (5) editing the total deck of stands to smaller, frequently more homogenous

subsets for analysis.

DEVELOPMENT OF CLASSIFICATION

Computer and subjective analysis of the stand data proceeded concurrently through the series of steps shown in figure 2. The subjective analysis followed standard phytosociological procedures, i.e., the preparation and comparison of numerous stand tables. From previous research in the area (ROTHACHER, DYRNESS, and FREDRIKSEN 1967), we were already aware of several generalized community types associated with various parts of the presumed moisture gradient. Additional groupings were sought through stand table analysis typically progressing from the distinctive community types associated with extreme site conditions (very dry, wet, or cold) to those found under more moderate site conditions.

The first computer analyses showed some of the difficulties associated with computer selection of reference or end stands for the ordination. For example, extremely unusual (unique) stands were sometimes chosen; such stands have little in common with any other stands, and consequently, the majority remained in the center of the ordination near the mid-points of both the x and y axes. This is undesirable, since one of the objectives of the analysis is to disperse the stands over the area of the ordination so that groups or clusters of high similarity can be identified. A second problem was that reference stands at opposite ends of the x and y axes often represented a warm, dry community and a cold, wet community. Hence, each axis represented a combined moisture and temperature gradient. We found it desirable to designate end stands for the x axis so that it represented the apparent moisture gradient in the *Tsuga heterophylla* (lower elevation) Zone. The y axis, whether the end stands were selected by us or by computer, then usually represented an apparent temperature (elevation) gradient (fig. 3).

Following completion of each set of successful computer runs, the results of the ordination were compared with the groupings developed from the subjective analysis. Often there was good correlation between the tentative commu-

nity types and the clustering of stands on the ordination. In other cases, the location of individual stands on the ordination made it obvious they had been mistakenly classified in the stand table analysis, and they were shifted to the more appropriate community type. In a few, but sometimes significant cases, tentative community types were shown to be highly artificial by the wide scattering of the member stands through the ordination. These community types were reexamined and some or all of the member stands reassigned to various other groups as suggested by the ordination. Some large blocks of stands had proved very difficult to subjectively classify, e.g., stands with rich and varied herbaceous understories in the *Abies amabilis* Zone. Ordinations often identified major subgroups or community types within these blocks, i.e., supplying the clues necessary for the subjective analysis to proceed.

Subjective evaluations of the computer analyses resulted in continuous modification of the ordination procedure, as well. The ordinations were not always ecologically sound, and clusters sometimes contained stands distinctly different in character. One common problem was the lack of sufficient dispersion of the stands on the ordination. For these reasons, numerous analyses were conducted in which new end stands were selected or new sets of characters used for the similarity computations. It was impossible to progress very far analyzing all 300 stands which varied so widely in characteristics in one analysis. Therefore, many analyses were made using subsets of stands, e.g., those which had *Abies amabilis* as a climax species (i.e., the stands from *Abies amabilis* Zone), or those which were second growth.

Hence, the classification was evolved through concurrent use of subjective and computer ordination analysis. The completed classification was believed to be better than any which would have been developed using either method alone. Most of the community types identified early in the subjective analysis remained. The ordination analysis had modified them so that they were more sharply defined and homogenous, however.

Plot No.												
<i>Tsuga/Rhododendron</i>	9											
	47	37										
	8	37	47									
	5	52	43	61								
	19	45	43	54	47							
	20	42	48	51	44	50						
<i>Abies/Tiarella</i>	205	39	33	40	31	45	33					
	265	7	21	19	10	5	13	8				
	14	9	14	17	15	10	16	11	54			
	53	15	18	27	18	16	25	16	42	57		
	52	9	15	25	15	10	19	14	49	38	53	
	266	6	14	19	10	8	17	8	72	50	49	45
	238	8	15	21	12	5	16	9	58	52	49	63
	83	6	15	20	7	3	18	8	47	44	42	47
		9	47	8	5	19	20	205	265	14	53	52
										286	238	
<i>Tsuga/Rhododendron</i>								<i>Abies/Tiarella</i>				

Figure 4. — An example of a small similarity matrix involving stands representative of two community types. Although similarity index values within each community are at least moderately high, between-community values are low, indicating that the *Tsuga/Rhododendron* and *Abies/Tiarella* communities have few characteristics in common.

A few tentative community types were completely dropped and some added as a result of the ordinations.

The final steps involved final refinements in the classification and preparation for field use. First, the similarity matrices, in which all stands are compared with one another, were studied carefully both within and between community types (fig. 4). In this way, the homogeneity of each type was studied — the higher the similarity values, the more homogeneous the community type. Individual stands having low similarity with others in the same community type were

identified and reexamined to determine whether they should be left in that group or were better assigned to another. A key to the community types was then prepared. The computer was used to check the accuracy of the key by assigning each stand according to the stated criteria. Finally, association tables were prepared for each community type summarizing in tabular form the environmental and vegetative characteristics of each (fig. 5).

USE OF ENVIRONMENTAL DATA

It might appear that environmental data were not used in developing the classification, but, in

Figure 5. — Association table for the *Pseudotsuga/Holodiscus* community. Note that values are given for each of the 8 stands, as well as summary cover and constancy values for the entire community

	Stand 28	Stand 98	Stand 137	Stand 143	Stand 145	Stand 278	Stand 279	Stand 287
Landform	Uneven slope	Smooth slope	Smooth slope	Smooth slope	Smooth slope	Ridge top	Smooth slope	Smooth slope
Elevation (feet)	1,500	2,800	1,700	2,200	2,000	1,600	1,700	2,000
Slope (percent)	60	99	40	75	70	50	65	85
Aspect	S	W	S	SW	SW	SW	SW	SW
Soil series	Frissell	Lithosol	Lithosol	Green	Green	—	—	—
Parent material	Pyroclastics	Andesite	Pyroclastics	Pyroclastics	Pyroclastics	—	—	—
Rooting depth (feet)	2-3	1-2	1-2	3-4	1-2	—	—	—
A Horizon thickness (ins.)	4-6	2-4	2-4	4-6	4-6	—	—	—
A Horizon texture	Sandy loam	Loam	Silt loam	Silty clay loam	Loam	—	—	—
Profile stoniness (%)	70-80	49-50	50-60	30-40	20-30	—	—	—
Soil drainage	Well drained	Well drained	Well drained	Well drained	Well drained	—	—	—
Climax tree species A	<i>Pseudotsuga</i>	<i>Libocedrus</i>	<i>Pseudotsuga</i>	<i>Pseudotsuga</i>	<i>Libocedrus</i>	<i>Pseudotsuga</i>	<i>Pseudotsuga</i>	<i>Pseudotsuga</i>
Climax tree species B	<i>Pseudotsuga</i>	<i>Pseudotsuga</i>	<i>Pseudotsuga</i>	<i>Libocedrus</i>	<i>Pseudotsuga</i>	<i>Pseudotsuga</i>	<i>Pseudotsuga</i>	<i>Pseudotsuga</i>
Forest age class	Old growth (over 300 yrs)	Young (100-150 yrs)	Old growth (over 300 yrs)	Old growth (over 300 yrs)	Old growth (over 300 yrs)	Old growth (over 300 yrs)	Young (100-150 yrs)	Old growth (over 300 yrs)
Canopy density (%)	60-70	50-60	20-30	60-70	30-40	40-50	50-60	30-40
Site quality	III-	V	V	III-	V	V	IV	IV+

Figure 5. — (Continued)

	Stand 28	Stand 98	Stand 137	Stand 143	Stand 145	Stand 278	Stand 279	Stand 287	Average % cover	% Constance
TREE LAYER										
<i>Acer macrophyllum</i> (Reprod)	10	-0	-0	-0	-0	-0	-0	10	2	25
<i>Acer macrophyllum</i> (Mature)	1	-0	-0	-0	-0	-0	-0	-0	0	12
<i>Arbutus menziesii</i> (R)	-0 ¹⁾	-0	1	-0	-0	-0	-0	-0	0	12
<i>Arbutus menziesii</i> (M)	-0	-0	5	8	5	-0	-0	-0	2	37
<i>Libocedrus decurrens</i> (R)	-0	10	-0	1	10	-0	-0	-0	2	37
<i>Libocedrus decurrens</i> (M)	-0	10	-0	15	20	-0	5	0	6	50
<i>Pinus lambertiana</i> (R)	1	-0	-0	1	1	-0	-0	-0	0	37
<i>Pinus lambertiana</i> (M)	1	-0	-0	1	-0	-0	5	2	1	50
<i>Pseudotsuga menziesii</i> (R)	15	2	15	4	10	3	2	10	7	100
<i>Pseudotsuga menziesii</i> (M)	35	40	30	40	40	40	65	40	41	100
GROUND LAYER										
<i>Acer circinatum</i>	25	3	12	30	-0	8	2	70	18	87
<i>Berberis nervosa</i>	35	25	5	25	1	7	4	27	16	100
<i>Castanopsis chrysophylla</i>	1	-0	2	2	-0	-0	-0	1	1	50
<i>Cornus nuttallii</i>	1	-0	7	-0	-0	-0	2	3	1	50
<i>Corylus cornuta</i> var. <i>californica</i>	25	5	5	-0	3	11	2	7	7	87
<i>Gaultheria shallon</i>	0 ²⁾	-0	4	50	2	-0	-0	2	7	62
<i>Holodiscus discolor</i>	6	2	15	-0	2	8	3	2	5	87
<i>Rosa gymnocarpa</i>	1	1	-0	-0	1	1	1	-0	1	62
<i>Symphoricarpos mollis</i>	1	-0	7	1	1	3	1	1	2	87
<i>Taxus brevifolia</i>	20	1	-0	-0	-0	10	-0	-0	4	37
<i>Vaccinium parvifolium</i>	1	-0	2	-0	-0	2	1	2	1	62
<i>Acer glabrum</i> var. <i>douglasii</i>	0	1	-0	-0	-0	-0	-0	-0	0	25
<i>Amelanchier</i> sp.	-0	-0	5	-0	-0	0	-0	1	1	37
<i>Pachistima mrsinites</i>	-0	2	-0	-0	-0	-0	-0	-0	0	12
<i>Rhus diversiloba</i>	1	-0	-0	-0	-0	-0	0	-0	0	25
<i>Lonicera ciliata</i>	-0	-0	1	-0	-0	-0	1	-0	0	25
<i>Achlys triphylla</i>	1	-0	-0	-0	-0	0	0	1	0	50
<i>Anemone deltoidea</i>	-0	-0	1	-0	-0	0	1	-0	0	37

Figure 5. — (Continued)

	Stand 28	Stand 98	Stand 137	Stand 143	Stand 145	Stand 278	Stand 279	Stand 287	Average % cover	% Constance
GROUND LAYER (Cont.)										
<i>Chimaphila menziesii</i>	1	-0	-0	-0	-0	-0	-0	-0	0	12
<i>Chimaphila umbellata</i>	2	1	-0	1	2	0	1	1	1	87
<i>Galium triflorum</i>	-0	-0	-0	-0	-0	1	0	1	0	37
<i>Goodyera oblongifolia</i>	1	1	-0	1	1	0	0	1	1	87
<i>Hieracium albiflorum</i>	3	2	-0	-0	2	1	1	-0	1	62
<i>Linnaea borealis</i>	4	-0	10	2	-0	1	1	3	3	75
<i>Listera</i> spp.	-0	1	-0	-0	-0	-0	-0	-0	0	12
<i>Polystichum munitum</i>	4	1	2	3	1	3	3	17	4	100
<i>Pteridium aquilinum</i>	-0	-0	-0	1	-0	-0	-0	-0	0	12
<i>Rubus ursinus</i>	1	-0	1	1	-0	1	1	1	1	75
<i>Synthyris reniformis</i>	15	-0	4	-0	2	2	3	8	4	75
<i>Trientalis latifolia</i>	3	1	1	1	2	1	1	1	1	100
<i>Vancouveria hexandra</i>	1	-0	-0	-0	-0	-0	0	-0	0	25
<i>Viola sempervirens</i>	-0	-0	-0	-0	-0	-0	-0	1	0	12
<i>Whipplea modesta</i>	4	7	5	1	10	10	17	7	8	100
<i>Xerophyllum tenax</i>	-0	-0	10	2	-0	-0	-0	-0	2	25
<i>Adenocaulon bicolor</i>	-0	-0	1	-0	-0	0	0	1	0	50
<i>Anemone lyallii</i>	-0	-0	1	-0	1	-0	-0	-0	0	25
<i>Campanula scouleri</i>	-0	-0	1	-0	2	-0	1	3	1	50
<i>Fragaria</i> sp.	-0	1	-0	-0	-0	1	-0	-0	0	25
<i>Galium oregana</i>	1	0	0	0	0	0	0	0	0	12
<i>Grass</i>	5	3	3	1	-0	2	2	1	2	87
<i>Iris tenax</i>	-0	-0	1	-0	2	1	1	1	1	62
<i>Lathyrus polyphyllus</i>	-0	-0	-0	1	20	-0	1	0	3	37
<i>Luzula</i> sp.	-0	-0	-0	-0	1	1	1	-0	0	37
<i>Osmorhiza</i> sp.	-0	-0	-0	-0	-0	-0	-0	1	0	12
<i>Arenaria macrophylla</i>	1	1	-0	-0	-0	1	0	-0	0	50
<i>Collomia heterophylla</i>	-0	-0	-0	-0	5	1	1	-0	1	37
<i>Madia</i> sp.	-0	-0	3	-0	1	1	1	-0	1	50

1) Indicates species was not present.

2) Indicates species was present in trace amounts.

fact, they were. For example, the environmental features of each tentative grouping or community type were continuously examined during the development of the classification. We wanted the community types relatively homogeneous not only in vegetative but also in environmental features. The stands within tentative types were typically quite consistent in elevation, slope, aspect, effective rooting depth, stoniness, and landform. Individual stands which differed significantly in environmental features were often segregated as phases or reassigned to other community types.

Of course, the basic structure of the ordinations and final classification was environmental — along apparent moisture and temperature gradients in our area. A number of vegetation classification studies have shown that ordination procedures such as SIMORD used in the H.J. ANDREWS study yield a classification along environmental gradients (WHITTAKER 1967). Vegetation is, in fact, the most sensitive integrator of habitat factors. Vegetation associations are convenient guideposts in a complex environmental field.

In a study of forest associations in Poland, 10 associations were determined by BRAUN-BLANQUET floristic inventories. Further analyses of these associations, using similarity and ordination techniques, indicated the distinctiveness of each association along gradients of wet-dry and infertile-fertile habitat conditions (FRYDMAN and WHITTAKER 1968). In similar manner, the associations of the H. J. ANDREWS Experimental Forest occupy positions along wet-dry and warm-cool (elevational) gradients of environmental conditions. The environmental data collected in our reconnaissance are used to corroborate the validity of these gradients. Within each association, soil profile features, position of each stand in the mountain landscape, and forest productivity class (which reflects habitat fertility and other site growth factors) were reasonably uniform. Thus, the environmental data lends substance to the classification, based on floristic data. It is not to be expected, of course, that all environmental data

are of like importance in accounting for vegetation distribution. Only those environmental features to which individual plant species have strong responses are useful as classification aids.

Applications and limitations of the reconnaissance method value of habitat type classifications

Classifications of forest lands based on communities and environment have, of course, many practical applications in both forest management and research. Community types are themselves useful biological indicators of site conditions, especially when climax elements are emphasized in the classification. In our system, environmental features are also used directly in the classification. Therefore, the classification is of habitat or site types as well as of community types and is of broader and less transient usefulness.

The value of habitat-type classifications in forestry practice has been demonstrated repeatedly in North America. Selection of species for management is an important application — a guide to which species (or combination) will grow best on a given site. Studies in the northern Rocky Mountains have shown, for example, that *Pinus ponderosa* is unsuitable for planting on habitats cooler or more moist than those characterized by the *Abies grandis*/*Pachistima myrsinites* community. Pathological problems and required silvicultural techniques vary with habitat type, as do growth and productivity of a given species. Dwarf mistletoe (*Arceuthobium* spp.) is a problem on some habitat types in the northern Rocky Mountains and not on others (DAUBENMIRE and DAUBEMIRE 1968). In the Cascade Range, balsam woolly aphid is a serious insect problem on *Abies amabilis* only on certain habitat types and not on others (FRANKLIN 1966). On the H. J. ANDREWS Experimental Forest, adequate regeneration of *Pseudotsuga* requires a shelterwood technique on some habitats (e.g., those characterized by the *Pseudotsuga*/*Holodiscus* community), whereas clearcutting is suitable on other habitats.

Community and habitat classifications are

extremely useful in research; in fact, this is the primary purpose for which we developed ours. The H. J. ANDREWS Experimental Forest is an area of intensive forest research, including an intensive study site for the U.S. International Biological Program. A classification was needed to stratify the area into reasonably homogenous community and habitat types to aid in placement of research plots and in the extrapolation of resulting data.

ADVANTAGES OF THE RECONNAISSANCE METHOD

A small team of trained field observers can use the reconnaissance method to considerable advantage. The number of forest stands analyzed in a field day is considerably greater than would be obtained by slower, more deliberate mensuration techniques. The loss of precision from estimative procedures is not necessarily a serious drawback in forest classification, since the variation between stands in a forest association is often considerably greater than variation due to estimation of stand vegetation characteristics. In the *Pinus ponderosa* Zone of Colorado, U.S.A., one of the authors (W. H. Moir) has found that the stands measured both analytically and by estimative procedures have similarities in excess of 80 percent, and sometimes over 90 percent, when data taken from the same stand by different methods are compared. When used with more exact mensurational procedures of stand analysis, the reconnaissance method is a powerful tool for both classification and regional survey. Approximately every tenth stand can be "double sampled," first by visual estimation of vegetation characteristics, and then by quantitative measurement. Double-sampled stands are used to ascertain the precision of reconnaissance estimates, using correlation procedures, and serve to further improve the observer's ability to visually estimate vegetation characteristics.

Classification based upon forest reconnaissance can be used to establish expensive, long-term observational stations in model habitats (DAUBENMIRE 1966). The pattern of classification that emerges from effective field reconnaissance is all the more valid because of the large

number of stands that have been included in the classification procedure. Variation within and between habitats can be more easily defined, and certain, more important, habitat types, or vegetation associations, can be identified for subsequent study or experimentation. Without an overall sense of regional vegetation variation, it might be difficult in the final analysis to justify the selection of certain stand types for productivity, micrometeorological, soil chemistry, or other types of expensive and complex forest studies.

Rapid regional surveys of vegetation, soils, or other natural resources are of considerable importance, especially in areas of rapid development or change. Regional planning and resource inventory is imperative wherever swelling human population calls for increasing resource exploitation. Remote sensing is becoming an effective procedure for regional forest inventories (National Academy Sciences 1970). However, interpretation of imagery and other analog data of remote sensing is possible only by acquisition of ground truth data such as that provided by reconnaissance crews. Clearly, detailed analytical procedures of vegetation description would not allow adequate coverage of large regional areas.

A reconnaissance method of this type also has an advantage in flexibility. The specific bits of environmental and biologic data selected for collection at each plot can be readily altered to suit the purpose of the survey, the natural features of the region, and the inclinations of the research team doing the work. In planning a similar survey in the subalpine forests of central Honshu, additional data will be collected to meet particular circumstances of that study, e.g., basal area by species using a wedge prism.

LIMITATIONS OF THE RECONNAISSANCE METHOD

Certain drawbacks to the reconnaissance method should be pointed out. Each member of the field survey team should already be familiar with his resource specialty in the region being sampled. In the H. J. ANDREWS Experimental Forest, the vegetation, soils, and landform geomorphology were well known to the authors

from previous experience there (FRANKLIN and DYRNESS 1969). Uncertainty about vegetation, soils, or geomorphology reduces the efficiency of the estimative method and introduces errors or omissions in the recorded data. A reconnaissance stand is usually visited only once. Vegetation periodicity is therefore apt to produce omissions and inaccuracies in the record, especially in stands that have many ephemeral species or strong seasonal changes in dominance. The soil profile is determined from only one pit site, and thus variation in profile depth and other characteristics within a stand remains unknown. It is possible that certain soil characteristics attributed to the stand from the single sample site do not, in fact, describe the typical stand condition.

Literature cited

BRAY, J. R., AND CURTIS, J. T.

1957. An ordination of the upland forest communities of southern Wisconsin. *Ecol. Monogr.* 27: 325-349.

DAUBENMIRE, R.

1959. A canopy-coverage method of vegetational analysis. *Northwest Sci.* 33: 43-64.

DAUBENMIRE, R. F.

1966. Vegetation: Identification of typical communities. *Science* 151: 291-298.

DAUBENMIRE, R., and DAUBENMIRE, JEAN B.

1968. Forest vegetation of eastern Washington and northern Idaho. *Wash. Agr. Expt. Sta. Tech. Bull.* 60, 104 pp.

DICK-PEDDIE, W. A., and MOIR, W. H.

1970. Vegetation of the Organ Mountains, New Mexico. *Colo. State Univ. Range Sci. Dept. Sci. Ser.* 4, 28 pp.

FRANKLIN, JERRY FOREST

1966. Vegetation and soils in the subalpine forests of the southern Washington Cascade Range. 132 pp., illus. (Unpublished Ph.D. thesis on file at Wash. State Univ., Pullman)

FRANKLIN, JERRY F., and DYRNESS, C. T.

1969. Vegetation of Oregon and Washington. U.S.D.A. Forest Serv. Res. Pap. PNW-80, 216 pp.

FRYDMAN, I., and WHITTAKER, R. H.

1968. Forest associations of southeast Lublin Province, Poland. *Ecology* 49: 896-908.

GOFF, F. GLENN

1968. Use of size stratification and differential weighting to measure forest trends. *Amer. Midland Natur.* 79: 402-418.

MCINTOSH, ROBERT P.

1967. A continuum concept of vegetation. *Bot. Rev.* 33: 130-187.

NATIONAL ACADEMY OF SCIENCE

1970. Remote sensing with special reference to agriculture and forestry. 424 pp. *Nat. Acad. Sci.: Washington, D.C.*

ROTHACHER, JACK, DYRNESS, C. T., AND FREDRIKSEN, RICHARD L.

1967. Hydrologic and related characteristics of three small watersheds in the Oregon Cascades. *USDA Forest Serv. Pac. Northwest Forest & Range Exp. Sta. Misc. Pub.*, 54 pp.

WHITTAKER, R. H.

1967. Gradient analysis of vegetation. *Biol. Rev.* 42: 207-264.

(Received for Publication October, 1970)

概査による森林立地区分法

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松井光瑤*抄訳

造林学者や森林生態学者は、施業に役だてるための森林型や立地区分の分野で、多くの研究法を開発してきた。環境条件を強調したものもあれば、植生を主にしたものもある。残念ながら、われわれの知っている方法は精査が必要であり、時間のかかるものが殆どである。広範囲にわたって速やかに情報を得たい場合の方法は米国西では研究されることがなかった。そこで、われわれは、迅速概査による区分法の開発が望ましいと考えた。迅速法によれば、より多くの林分を調査することができるから、少ない時間で、より変化に富んだサンプリングを、より広い地域にわたって調査することができる。少ない精査の代わりに、多くの概査プロットを取るわけである。環境因子は森林型区分および施業にとって重要な意味をもっているから、野外における迅速調査法に適合したものを植生調査と並行して記録しておく必要がある。しかし、迅速調査法では非常に多くのデータが蓄積されるから、このデータの分析にはコンピューターの助けをかりる必要が生じてくる。

われわれが森林立地区分のために開発して利用してきた迅速調査法が本論文の主題である。この方法を例示するために、われわれが米国の北西部オレゴンのカスケード山脈の温帯および亜高山帯森林で行なった、野外調査と用いた分析手法をあげ論議する。われわれが用いた個々の方法には何も新しいものはないが、個々の手法の組み合わせ方、とくに、主観的判断とより客観的なコンピューター法（類似性解析と順位解析）とを併用して解析し最終的な立地区分をしたことが異なっている。

この方法が他の温帯や亜高山帯にも有用であることが証明されれば一般的方法といえる。しかし、記録する諸性質の選択は、調査する地域の自然条件、分類の目的、研究チームの人選と能力などによって当然異なってくる。

目下、筆者等の1人 J.F. フランクリンは、日本の林業試験場の松井、前田両技官と協同で、本州中部の亜高山林の施業を目的として、この方法の適用を試みつつある。

調査地域

調査地は、オレゴン州中部のカスケード山脈の西向斜面にある温帯および亜高山帯針葉樹林からなる 6,000ha の試験林である。海拔高 500~1,600 m、地質は火山性

で、土壌は火山灰を母材とし、一般に深く、微粒質である。降水量は 2,300 mm 以上で、冬に多く夏は乾燥する。

調査地の自然植生は *Tsuga heterophylla* (温帯) 林と *Abies amabilis* (亜高山帯) 林とに分けられる。前者は 500~1,050m の高さに分布し、夏期乾燥気候帯であるため、その組成は乾湿による変化が大きい。後者は、1,050~1,600m に分布し、乾湿の差は顕著ではなく、組成および成長量は積雪期間および積雪量 (1~3m) の影響が大きい。大部分の森林は過去における山火のため、125年と 450 年の 2 つの齢階に分けられる。

野外調査法

われわれの目的は試験林内の森林組成と立地のすべてにわたるサンプリングにあったので、車道、歩道はすべてトランセクトをとり、これらの便のないところは、尾根から沢に至るトランセクトを取った。海拔高、傾斜、方位、土壌型のすべてについてサンプリングするように注意した。サンプル数は、これらの因子の重要度にはほぼ比例するように選んだ。トランセクトに沿ったサンプル地の選定は、一定間隔による組織的サンプル法と、林相や立地条件の差による主観的サンプル法とを併用した。組織的サンプル法は、林相の変化の少ない地域では最も重要である。植生のわずかな変化も見逃がさずにすむし、高度別のサンプルもすべて取ることができる。主観的サンプル法にのみ頼ると、広範囲にわたって均一な組成と見なして、不適当なサンプルを取りやすい。林分組成 (林齢、組成、成長状態) と立地条件 (傾斜度、方向、土壌型) の明瞭な差異は主観的サンプル法の指標になる。条件が著しく異なるときは、50~100m 間隔程度の近距離毎にサンプルされることもしばしばあった。サンプル地としての必要条件是、サンプリングに必要な広さと緩衝帯の広さにわたって均質であること (0.5ha あれば充分) で、明らかに他の林分との遷移帯であったり、均質性を欠く (プロット内に沢が流れるなど) ときは不都合である。林分の中の代表地点が実際のプロットとして選ばれる。

データの取り方

記録すべきデータ、プロットの大きさや形の決定にあたって、これは迅速概査法であることを心に止めておく必要がある。目的は、最少の時間で、植生や立地分類

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森林立地別刷

Reprinted from

Shinrin Richi

Vol. Ⅷ, No. 1

Meguro, Tokyo, Japan

November 1970